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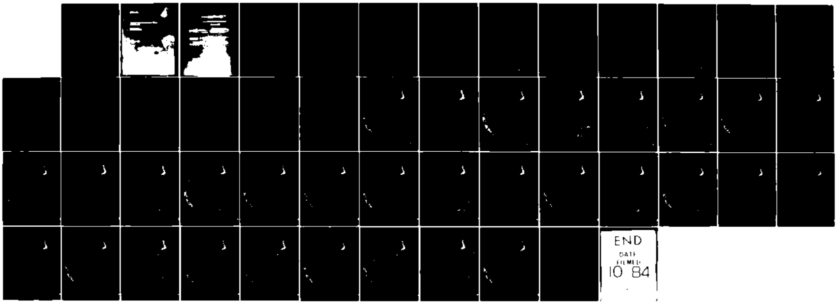

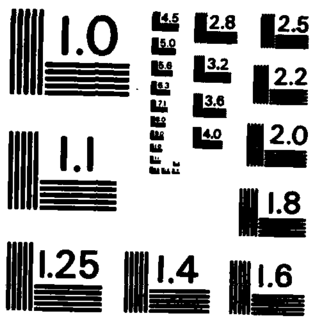

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SOUTHERN HEMISPHERE ATLAS OF 1-MINUTE RAINFALL RATES

Paul Tattelman
Donald D. Grantham

Errata

Page 10, seventh line from top:

Change: 3631 Northern Hemisphere locations

to read: 483 Southern Hemisphere locations

AIR FORCE GEOPHYSICS LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A model for estimating 1-min rainfall rates at a location for which routine climatic data are available was used to produce this atlas. Even though data were available for 483 locations, considerable subjectivity and smoothing of the analyses was required because of the low station-density in most areas. Southern Hemisphere analyses of rainfall rates equalled or exceeded 0.01, 0.05, 0.10, 0.50, and 1.0 percent of the time are presented for four mid-season months. Analyses of the highest rainfall rates for the same frequencies of occurrence regardless of the month in which they occur and

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companion analyses of the month in which the highest rate occurs are also presented.

Preface

We are grateful for the early programming support provided by Jack Mettauer, Regis College. Although very ill, he worked tirelessly until his sudden death during the course of this effort. We would like to thank Daniel Dechichio, Jr., Bedford Research Associates, for his responsive and timely programming support. We also thank Don Aiken, AFGL, for his programming support; Lisa Phillips, Systems and Applied Sciences Corp., for her extensive contribution to analyzing the charts; Arthur Kantor, AFGL, for his support and advice; and Helen Connell, AFGL, for typing the report.

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Southern Hemisphere Atlas of 1-Minute Rainfall Rates

1. INTRODUCTION

Knowledge of the frequency distribution of 1-min precipitation rates is important to the design and operation of many types of equipment. Precipitation, especially at heavier intensities, attenuates microwave signals of Air Force systems used in satellite detection and tracking, communications, air traffic control, and weaponry. Erosion caused by rain is important to the design and operation of helicopter rotor blades, leadings edges of aircraft and missiles, and fuses on airborne ordnance. Intense rainfall can cause jet engines to malfunction and can penetrate protective coverings on exposed electronic and mechanical materiel.

Rainfall climatologies are available for thousands of locations worldwide, in many instances for more than 100 years. However, data collection was oriented toward agricultural and hydrological purposes for which monthly, daily, and, less commonly, 3- and 6-hourly totals were collected. Precipitation data for intervals of 3 h down to 5 min are available for many locations in the United States but for few locations in other parts of the world. Much of the meager amount of data on 1-min rates were collected during special field programs conducted for limited time periods (1-3 years). This has prompted the development of numerous models to estimate 1-min rates (often referred to as instantaneous rates). Tattelman and

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Grantham[1] discuss sources of 1-min data and compare models for estimating 1-min rates.

A model for estimating rates on a monthly basis was developed at AFGL by Lenhard.[2] Because of the importance of worst-month considerations for design and operation problems, an improved monthly model that overcomes some of the shortcomings of the Lenhard model was developed by Tattelman and Scharr.[3] This model was used to estimate 1-min rainfall rates at 3631 Northern Hemisphere locations to produce this atlas.

2. THE MODEL

The Tattelman-Scharr model for estimating 1-min rainfall rates was developed using stepwise multiple regression analysis. Data for the analysis were taken from reports by Jones and Sims[4] and Sims and Jones.[5] These reports include the monthly frequency distribution of 1-min rates for the 12 locations in Table 1. Three years of data were available for Urbana and two years for Paris, but much less was available for the other stations. Therefore, data for the same month in different years were averaged to avoid bias by the stations with longer records. This resulted in 122 monthly instantaneous precipitation-rate distributions for the 12 locations.

The model is made up of six regression equations to estimate rates that are equalled or exceeded for exceedance levels (p) = 0.01, 0.05, 0.10, 0.50, 1.0, and 2.0 percent of time during a month. Information required to make the estimates for each of the six exceedance levels (p) consists of monthly mean temperature, monthly mean precipitation, number of days in the month with precipitation (based on any of three threshold values that define a rainy day), and latitude. The mini-

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1. Tattelman, P., and Grantham, D.D. (1982) A survey of techniques for estimating short-duration precipitation rate statistics, Air Force Surveys in Geophysics No. 441, AFGL-TR-82-0357, AD A125705.
2. Lenhard, R.W. (1974) Precipitation intensity and extent, J. Rech. Atmos. 8:375-384.
3. Tattelman, P., and Scharr, K.G. (1983) A model for estimating 1-minute rainfall rates, J. Clim. Appl. Meteorol. 22 (No. 9).
4. Jones, D.M.A., and Sims, A.L. (1971) Climatology of instantaneous precipitation rates, AFCRL-TR-72-0430, Final Report, Contract F19628-72-C-0070, AF Cambridge Res. Lab., AD 749878, Illinois State Water Survey, Urbana, Ill.
5. Sims, A.L., and Jones, D.M.A. (1973) Climatology of instantaneous precipitation rates, AFCRL-TR-73-0171, Final Report, Contract F19628-69-C-0052, AF Cambridge Res. Lab., AD 760785, Illinois State Water Survey, Urbana, Ill.

Table 1. Locations and Number of Months of 1-Min Data Available for Model Development. Data for the same month in different years were averaged. The resulting calendar months of data are indicated

Station	Coordinates	Months of Data	Calendar Months of Data
1. Flagstaff, Ariz.	35° 14'N, 111° 45'W	4	2
2. Franklin, N.C.	35° 02'N, 83° 28'W	17	12
3. IL Gauge 97 (20 miles NW of Urbana)	40° 27'N, 88° 15'W	10	10
4. Island Beach, N.J.	39° 52'N, 74° 05'W	13	12
5. Majuro, Marshall Islands	7° 05'N, 171° 23'E	13	12
6. Miami, Fla.	25° 45'N, 80° 19'W	13	12
7. Panama, Canal Zone	09° 21'N, 79° 59'W	4	4
8. Paris, France	48° 52'N, 02° 20'E	24	12
9. Preston, England	53° 46'N, 02° 42'W	12	12
10. Reading, England	51° 28'N, 00° 59'W	13	12
11. Urbana, Ill.	40° 07'N, 88° 12'W	36	12
12. Woody Island, Alaska	57° 47'N, 150° 20'W	11	10

mum threshold amount of precipitation to define a rainy day varies with country. Three of the most common threshold values used worldwide to define a rainy day are 0.25 mm, 1 mm, and 2.54 mm. The number of rainy days during the month based on each of these threshold amounts, as well as monthly precipitation and monthly mean temperature, were observed coincident with the rain-rate frequencies. The number of days per month for another frequently used threshold called a "trace" differed only slightly from the number of days equal to greater than 0.25 mm, and was not used.

The basic form of the model equation is expressed by

$$R_p = A_p + B_p T + C_p I + D_p f(L, T) \qquad (1)$$

where R_p is the estimated precipitation rate (mm/min) for exceedance level p, T is the monthly mean temperature (°F or 1.8 x °C + 32), I is a precipitation index (monthly mean precipitation in mm divided by the monthly mean number of days with precipitation), and $f(L, T)$ is a latitude-temperature term. A_p is the constant for exceedance level p, and B_p, C_p, and D_p are multiple regression coefficients

for T, I, and f(L,T) respectively for exceedance level p. The term f(L,T) is defined by

$$f(L,T) = \begin{cases} 0 & L \leqslant 23.5^\circ \\ (L - 23.5)xT & 23.5 < L \leqslant 40^\circ \\ (40 - 23.5)xT & L > 40^\circ \end{cases} \tag{2}$$

where L is the latitude (degrees and tenths) of the location of interest. This term accounts for the increasing importance of temperature for estimating precipitation rates at latitudes higher than 23.5°N.

Results of the regression analysis, including the multiple correlation coefficient (R) and the standard error of estimate (SEE), for each of the 6 exceedance levels are given in Tables 2, 3, and 4 for indices based on rainy-day threshold values of 2.54 mm, 1 mm, and 0.25 mm, respectively. The original report on the model whould be referred to for a more thorough description of its development and validation.

Table 2. Results of Stepwise Multiple Regression Analysis for Exceedance Levels p = 0.0, 0.05, 0.10, 0.50, 1.0, and 2.0 Percent Based on a Threshold Value of 2.54 mm for I. The regression coefficients are given for each independent variable

p	Constant (A_p)	T (B_p)	$I_{(2.54)}$ (C_p)	f(L,T) ((D_p)	R	SEE (mm/min)
.01	-0.91	$2.8\text{X}10^{-2}$	$2.3\text{X}10^{-2}$	$-3.4\text{X}10^{-4}$	0.83	0.43
.05	-0.50	$1.6\text{X}10^{-2}$	$1.9\text{X}10^{-2}$	$-3.1\text{X}10^{-4}$	0.86	0.24
.10	-0.31	$1.1\text{X}10^{-2}$	$1.4\text{X}10^{-2}$	$-3.0\text{X}10^{-4}$	0.85	0.19
.50	-0.01	$2.5\text{X}10^{-3}$	$5.4\text{X}10^{-3}$	$-1.5\text{X}10^{-4}$	0.76	0.09
1.0	0.03	$7.4\text{X}10^{-4}$	$2.9\text{X}10^{-3}$	$-7.6\text{X}10^{-5}$	0.67	0.06
2.0	0.04	$-2.0\text{X}10^{-4}$	$1.5\text{X}10^{-3}$	$-3.2\text{X}10^{-5}$	0.64	0.02

3. MAPPING THE 1-MIN RATES

The Tattelman-Scharr model was used to calculate 1-min rainfall rates exceeded 1.0, 0.50, 0.10, 0.05, and 0.01 percent of the time during the month (approximately 7.3 h, 3.6 h, 44 min, 22 min, and 4.4 min, respectively). Although the model can also be used to estimate rates exceeded 2 percent of the time in a

Table 3. Results of Stepwise Multiple Regression Analysis for Exceedance Levels p = 0.01, 0.05, 0.10, 0.50, 1.0, and 2.0 Percent Based on a Threshold Value of 1 mm for I. The regression coefficients are given for each independent variable

p	Constant (A_p)	T (B_p)	$I_{(1.00)}$ (C_p)	f(L,T) (D_p)	R	SEE (mm/min)
.01	-1.00	2.8×10^{-2}	3.6×10^{-2}	-2.2×10^{-4}	0.84	0.41
.05	-0.56	1.6×10^{-2}	2.5×10^{-2}	-2.4×10^{-4}	0.88	0.23
.10	-0.36	1.1×10^{-2}	2.0×10^{-2}	-2.4×10^{-4}	0.87	0.18
.50	-0.03	2.4×10^{-3}	7.8×10^{-3}	-1.2×10^{-4}	0.79	0.09
1.0	0.02	6.9×10^{-4}	4.2×10^{-3}	-6.2×10^{-5}	0.71	0.05
2.0	0.04	-1.8×10^{-4}	2.0×10^{-3}	-2.6×10^{-5}	0.67	0.02

Table 4. Results of Stepwise Multiple Regression Analysis for Exceedance Levels p = 0.01, 0.05, 0.10, 0.50, 1.0, and 2.0 Percent Based on a Threshold Value of 0.25 mm for I. The regression coefficients are given for each independent variable

p	Constant (A_p)	T (B_p)	$I_{(0.25)}$ (C_p)	f(L,T) (D_p)	R	SEE (mm/min)
.01	-1.00	2.8×10^{-2}	4.2×10^{-2}	$-2.\times10^{-4}$	0.85	0.41
.05	-0.56	1.6×10^{-2}	3.0×10^{-2}	-2.3×10^{-4}	0.88	0.22
.10	-0.36	1.1×10^{-2}	2.4×10^{-2}	-2.3×10^{-4}	0.88	0.17
.50	-0.03	2.3×10^{-3}	1.0×10^{-2}	-1.2×10^{-4}	0.82	0.08
1.0	0.01	5.6×10^{-4}	6.0×10^{-3}	-5.6×10^{-5}	0.77	0.05
2.0	0.03	-2.3×10^{-4}	2.8×10^{-3}	-2.4×10^{-5}	0.74	0.02

month (approximately 14.5 h), these rates were not used for this atlas. A symbol representing a specified range of rates for each exceedance level at each location was then plotted on the AFGL equal-area map of the Southern Hemisphere used for this atlas. A publication by the USAF Environmental Technical Applications Center[6] was used to obtain model input data for the 483 individual stations used for the Southern Hemisphere. Data for a location were used only if the period-of-record

6. USAF Environmental Technical Application Center (1971) Worldwide Airfield Climatic Data, I-X; also published by U.S. Naval Weather Service as U.S. Naval Weather Service Worldwide Airfield Summaries.

was greater than 5 years. The spatial distribution of the locations used to make rate estimates is shown in Figure 1.

Tattelman and Scharr subjectively evaluated their model by estimating rates at independent locations representing a wide variety of the earth's climates. Results indicate circumstances when the model is either invalid or should be used with discretion. This occurred for very dry or cold months for which there were little or no data among the dependent stations. The model was found to be generally invalid when any of the following conditions existed for a specific month at a location:

(1) $T \leqslant 32°F$ (0°C)

(2) $I < 2$ mm/day

(s) Number of rainy days < 1

Other model inconsistencies such as negative rates or increasing rates with increasing exceedance level (larger percent occurrence) occasionally occur when T is between 32°F and 40°F (0°C-4.4°C). Rates are very low when any of these conditions exist, and they fall into the lowest range of rates used for a plotting symbol at each exceedance level. Areas with < 1 rainy day per month are indicated on the charts.

At some locations, heavy but infrequent (1-3 rainy days) convective precipitation accounts for virtually all of the precipitation in one or more months. In these circumstances, the model may estimate rates for each of the six exceedance levels which, when integrated, result in a total rainfall much greater than the monthly mean precipitation. To deal with this, a coarse estimate of the monthly precipitation based on the estimated rates at each location was made, using the algorithm

$$\hat{P} = R_{.01} \times t_{.01} + \frac{R_{.01}+R_{.05}}{2}\left(t_{.05}-t_{.01}\right) + \frac{R_{.05}+R_{.10}}{2} \times \left(t_{.10}-t_{.05}\right) + \ldots \frac{R_{1.0}+R_{2.0}}{2}\left(t_{2.0}-t_{1.0}\right) \qquad (3)$$

where $\hat{P}$ = the estimated total monthly precipitation,

R_p = the rate estimated for exceedance probability (p), and

t = the number of min per month at each exceedance probability.

Locations where the estimated monthly precipitation calculated from Eq (3) exceeded 4 times the observed mean monthly precipitation were identified to aid in the analysis. This is discussed in Section 4. A factor of 4 was subjectively chosen for this check on model estimates after examining results for locations representing a variety of the earth's rainfall regimes.

4. METHODS USED TO ANALYZE THE MAPS

Rainfall-rate estimates for each location were assigned a symbol representing a specified range of rates at each exceedance level. For p = 0.01, 0.05, 0.10, 0.50, and 1.0 percent of the time, ranges of 0.20, 0.15, 0.10, 0.10, and 0.05 mm/min respectively were used. These ranges also represent the intervals between isolines for the analysis at each exceedance level. For example, on the analysis for p = 0.01 percent, if the estimated rate was between 0 and 0.199 mm/-min, a specific symbol/color was printed on the map for that location. If the rate was between 0.20 and 0.399 mm/min, another symbol/color was used, and the isoline representing the boundary between the two was labeled 0.20 mm/min.

The analyses of Southern Hemisphere charts for four mid-season months at each of five exceedance levels (p = 0.01, 0.05, 0.10, 0.50, 1.0 percent of the month) are provided in Figures 2-21. Rate estimates for all 12 calendar months were scanned to develop maps of the highest 1-min rainfall rates at each exceedance level regardless of the month in which they occurred. These are provided for each of the five exceedance levels in Figures 22, 24, 26, 28, and 30. Companion charts showing the month of the year in which the highest 1-min rates occurred for each exceedance level are provided in Figures 23, 25, 27, 29, and 31.

Because of the absence of data, there are no isolines in Antarctica, central South America, parts of the interior of Australia, and part of the interior of Africa. In mountainous terrain, rates varied considerably between nearby stations because of differences in elevation and/or exposure to sources of moisture. Consequently, elevations generally greater than about 1500 m are hatched on the maps, and isolines are dashed in these areas to indicate their uncertain validity. The dashed isolines are usually truncated and then resumed elsewhere at the edge of the mountainous area indicating either lack of data or extreme variability of rates. Dashed lines outside of hatched mountainous areas indicate a greater degree of subjectivity and, hence, uncertainty in the analysis. Dashed lines are used over water to connect isolines over adjacent land areas. All isolines over water areas reflect data from locations on land, and should not be considered an accurate analysis of rainfall rates over the water surface.

Locations where the model is not valid for estimating rates because there is less than one rainy day in the month are bounded by a line of alternating dashes and dots. These areas are frequently surrounded by regions with one to three rainy days for which rate estimates may be high (see Section 3). Therefore, rain-rate isolines were subjectively adjusted in the vicinity of locations for which the estimated monthly precipitation from Eq (3) exceeded 4 times the observed monthly precipitation. Either rain-rate gradients in some areas and months were too large to show all the isolines or there were insufficient data to depict the true gradient in

in the analysis. Under these circumstances, isolines are either eliminated or truncated.

For islands or island groups/chains, a value representing the middle of the range is shown if there is only one station with a rate estimate. Where there are two or more stations with estimates, the values of the bottom of the lowest range and the top of the highest range are shown.

In comparison to the mid-season charts, the most objective analyses are the charts of the highest 1-min rainfall rates at each exceedance probability regardless of the month in which they occurred (Figures 22, 24, 26, 28, and 30). This is because of the following reasons:

(1) There are a greater number of stations with valid data.
(2) Rate estimates for any month at a location were used only if the estimated monthly precipitation calculated from Eq (3) did not exceed 4 times the observed mean monthly precipitation.
(3) Rain-rate gradients are not as extreme.

5. MAP DISCUSSION

5.1 January (Figures 2-6)

As shown in Figures 2-6, highest rates during January occur along the northern coast of Australia, in Indonesia, in the interior portion of South America between about 20° S-30° S, and in part of South America close to the equator. Rates in these areas exceed 1.8 mm/min 0.01 percent of the time in the month. Extremely dry conditions with less than one rainy day in the month occur in a large portion of Peru and Chile and along the southwest coast of Africa.

5.2 April (Figures 7-11)

As shown in Figures 7-11, much of the tropics north of about 10°S has rates exceeding 1.6 mm/min 0.01 percent of the time during April, with the highest rates exceeding 1.8 mm/min in parts of Indonesia, equatorial Africa, and the northern coast of Brazil. Much of Peru, northern Chile, and part of the southwest coast of Africa have less than one rainy day during the month.

5.3 July (Figures 12-16)

As shown in Figures 12-16, rates are generally low in most areas during July, a mid-winter month in the Southern Hemisphere. Large areas in South America and Africa have less than one rainy day during the month. Highest rates, exceeding 1.6 mm/min 0.01 percent of the time, are generally confined to Indonesia.

5.4 October (Figures 17-21)

As shown in Figures 17-21, rates are generally low in most areas during October, and rates exceeding 1.8 mm/min 0.01 percent of the time are virtually confined to parts of Brazil. Large areas with less than one rainy day during the month are found in Peru, Chile, part of southwestern Africa, part of eastern Africa, and parts of northern Australia.

5.5 Worst Month (Figures 22, 24, 26, 28, and 30)

As shown in Figures 22, 24, 26, 28, and 30, the highest rates during the most severe month exceed 1.8 mm/min 0.01 percent of the time in a large part of South America north of 30° S, in northern Australia, in Indonesia, and in two small areas in equatorial Africa. Rates exceeding 2.0 mm/min 0.01 percent of the time are virtually confined to part of northern Brazil.

5.6 Month With the Highest Rates (Figures 23, 25, 27, 29, and 31)

As shown in Figures 23, 25, 27, 29, and 31, highest rates most often occur during the summer months (Dec, Jan, Feb) for all frequencies of occurrence. Some general exceptions are the southern parts of both Australia and South America. In these areas, winter rates are commonly the highest at frequencies of occurrence equal to or greater than 0.5 percent of the time.

6. OTHER CONSIDERATIONS

The model used to develop this atlas uses long-term climatic data ($>$ 5 years) as input. Therefore, rain-rate estimates are considered to represent a long-term average. These estimates may not be adequate for design problems for which a low risk is important, since year-to-year variations in the distribution of 1-min rates observed at a specific location can be quite large.

The charts presented herein are intended to present the spatial distribution of 1-min rainfall rates in the hemisphere. However, it should be noted that the analyses required a substantial amount of subjectivity, as discussed in Section 4, and smoothing of the isolines was necessary in areas with large local variations in rates. Therefore, it would be more appropriate to use the Tattelman-Scharr model when rate estimates for a particular location are required and the climatic input data are available.

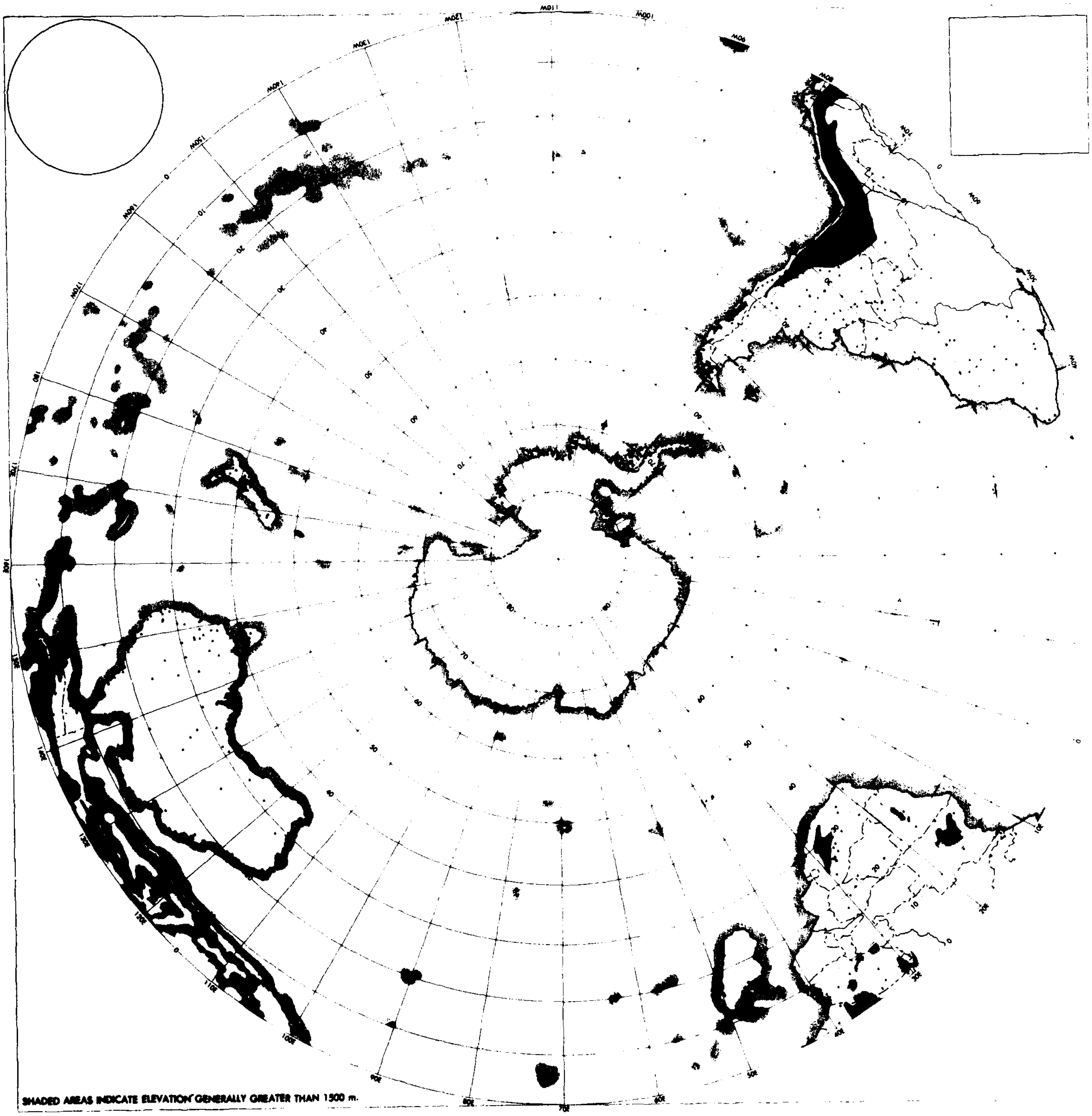

Figure 1. Spatial Distribution of Locations for Which Data Were Used

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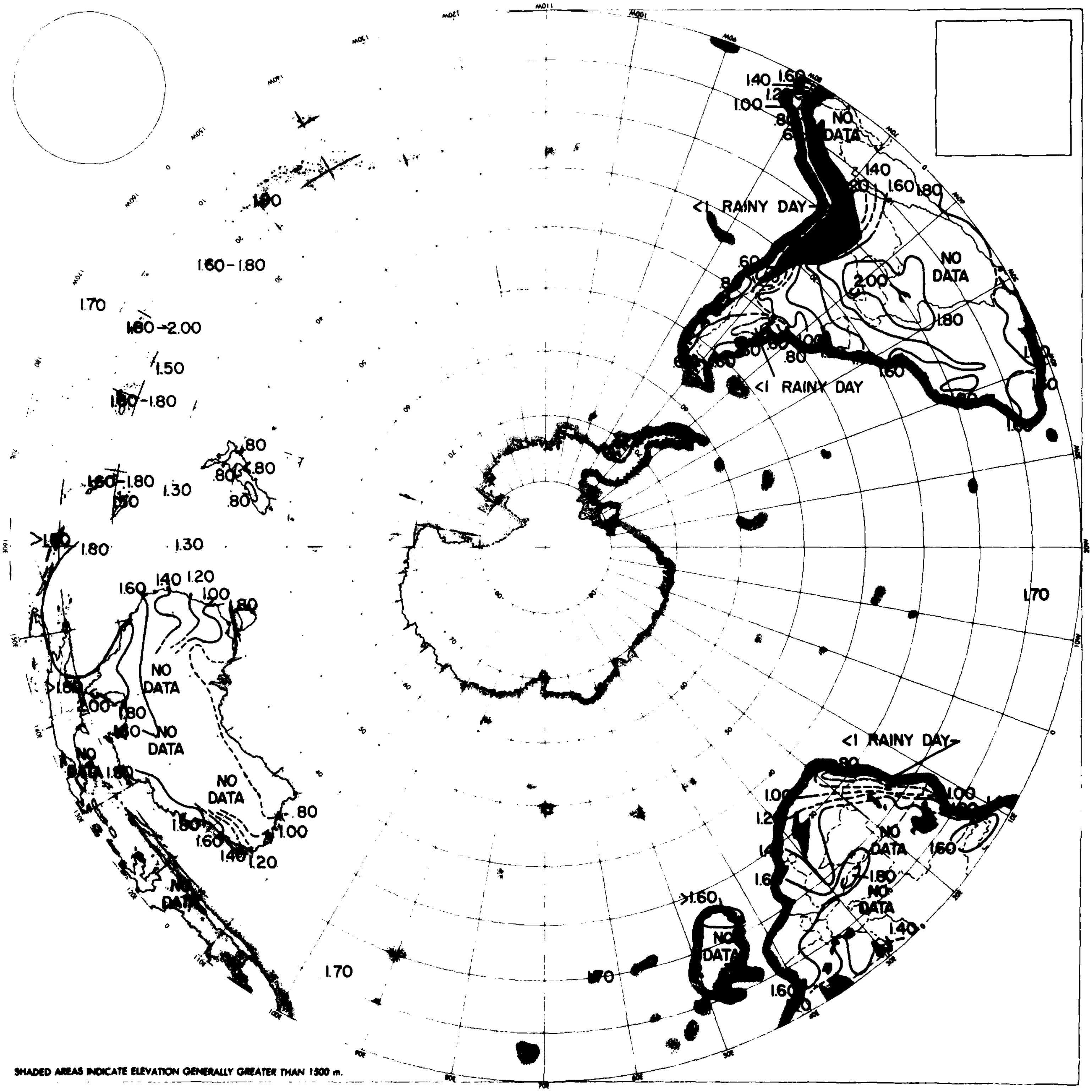

Figure 2. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.01 Percent of the Time in January

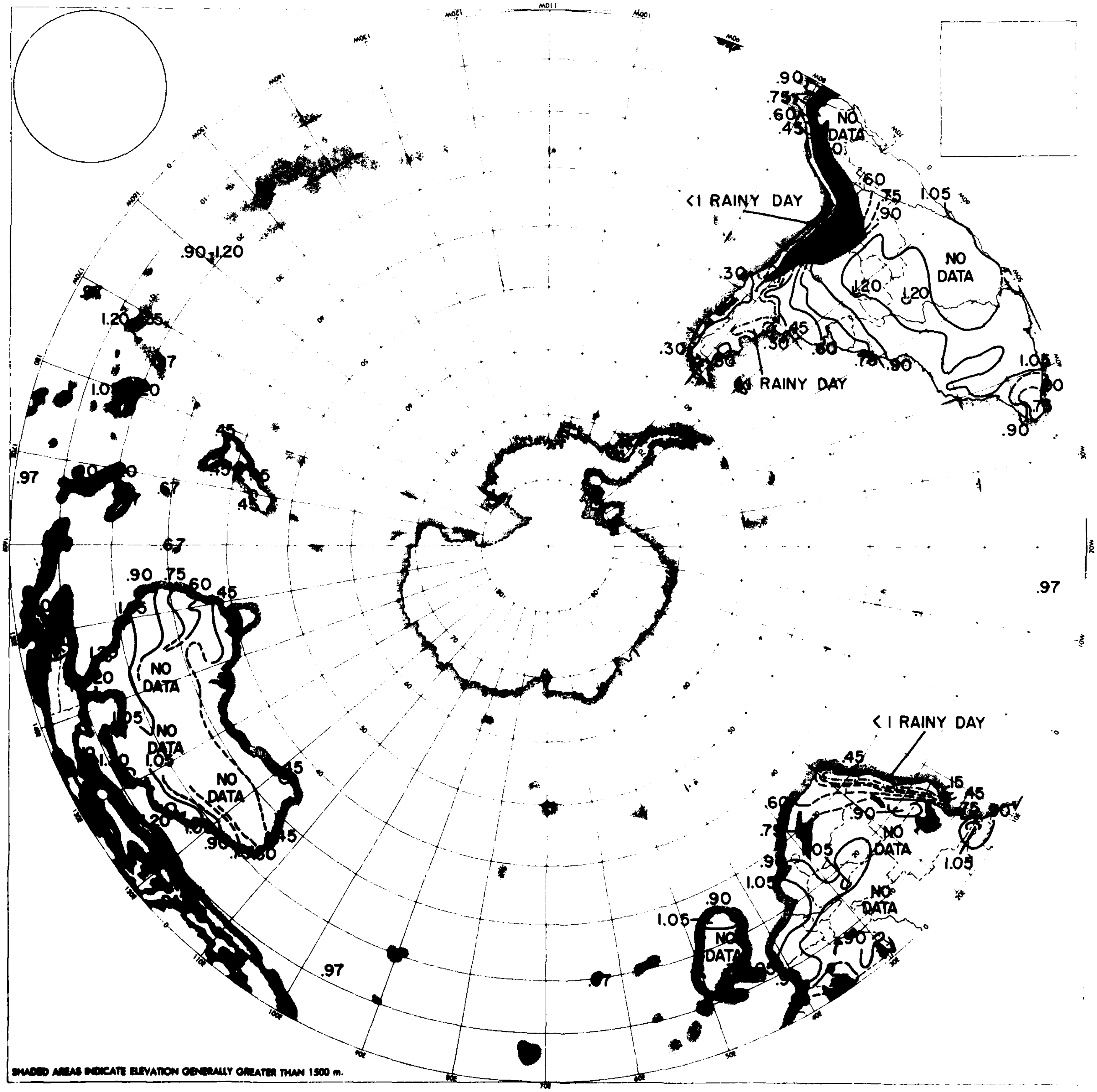

Figure 3. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.05 Percent of the Time in January

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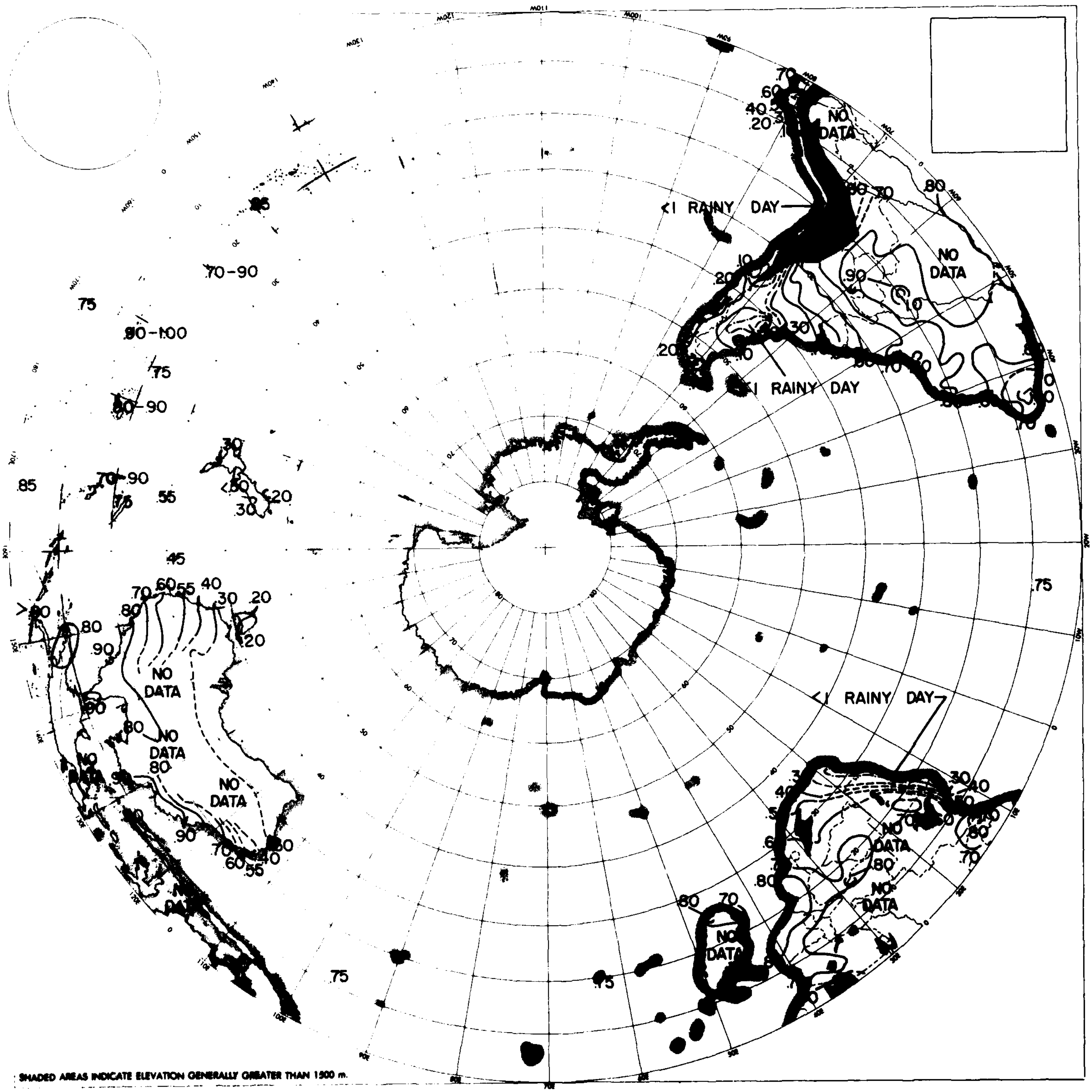

Figure 4. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.10 Percent of the Time in January

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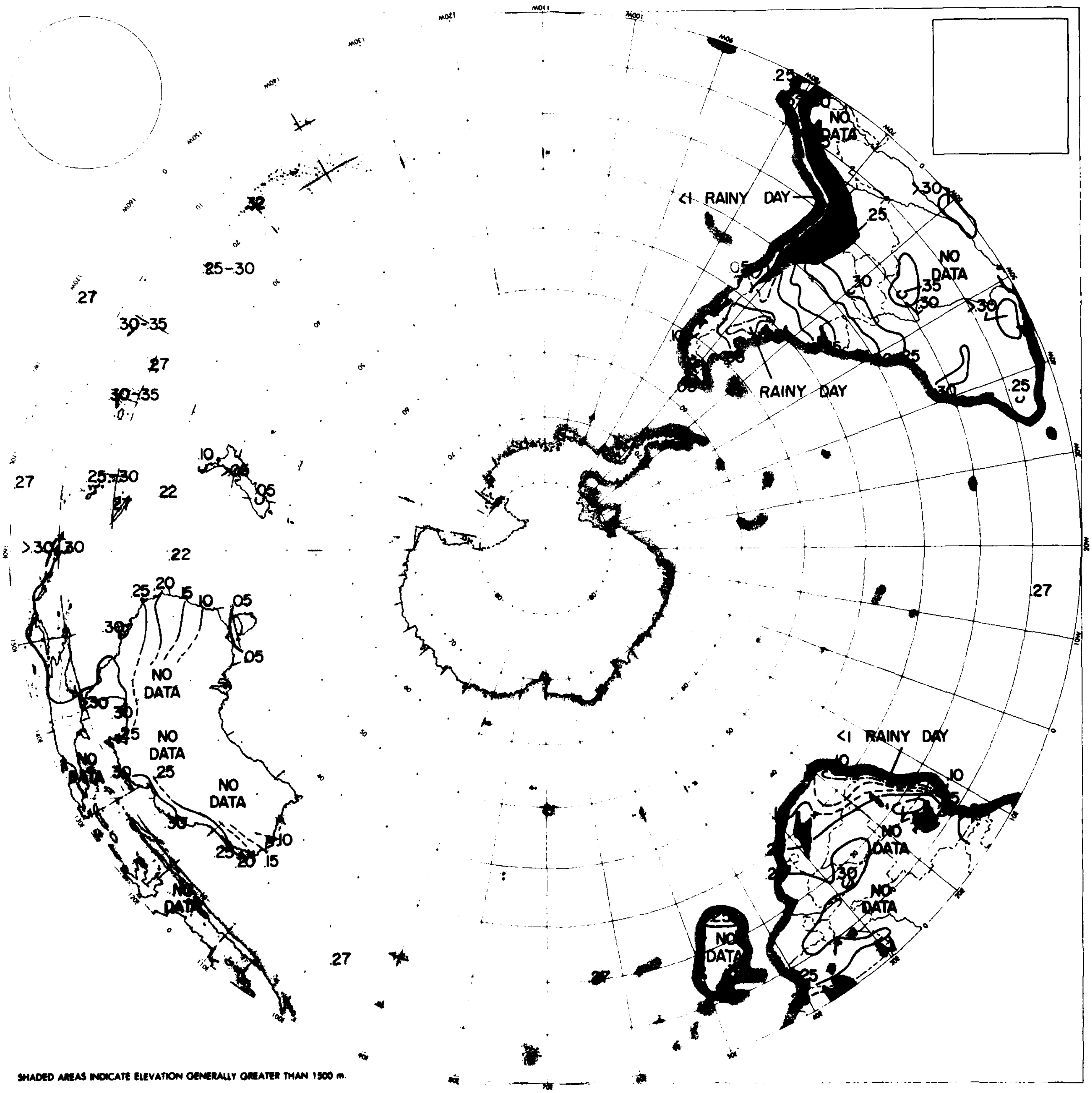

Figure 5. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.50 Percent of the Time in January

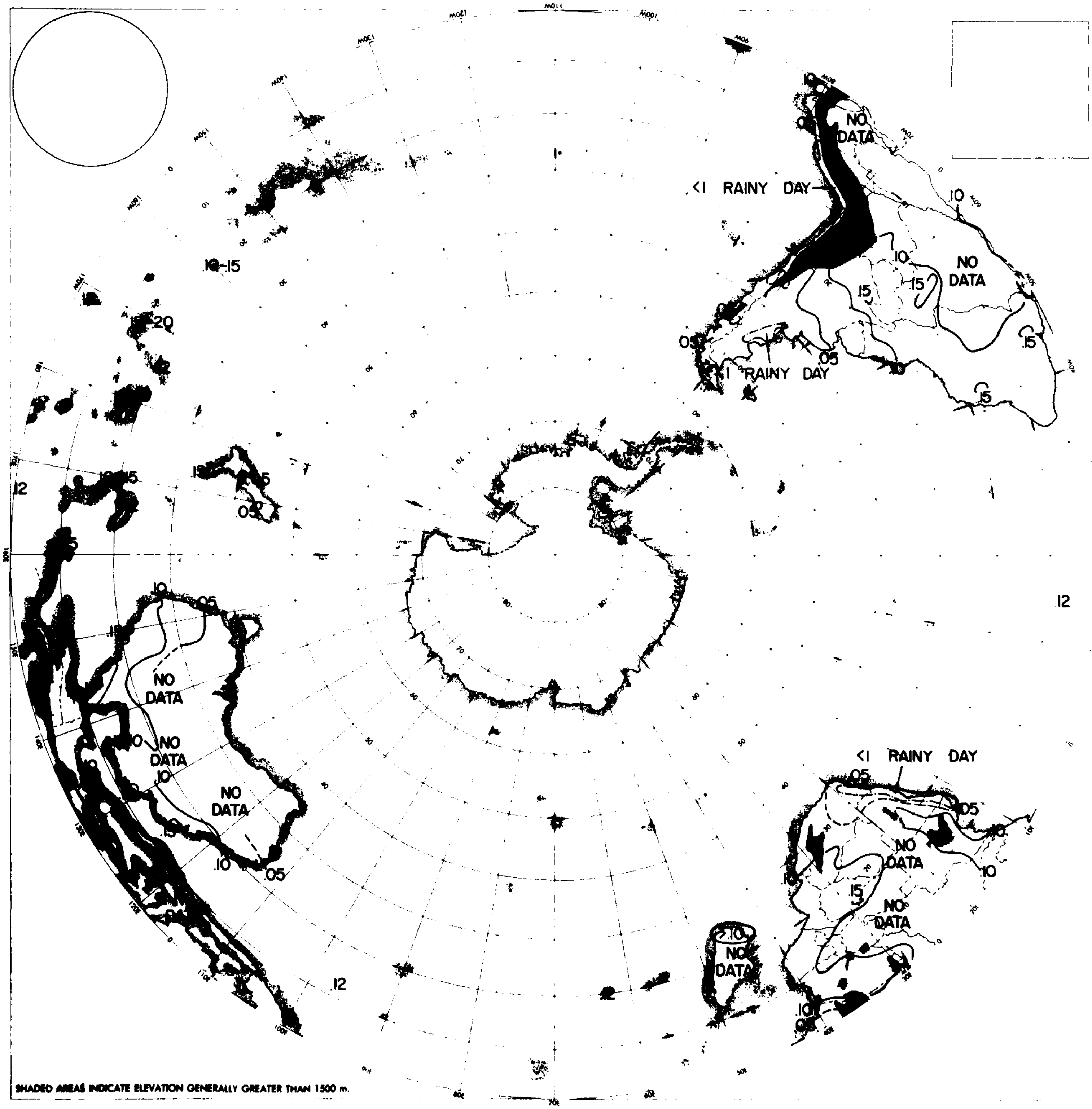

Figure 6. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 1.0 Percent of the Time in January

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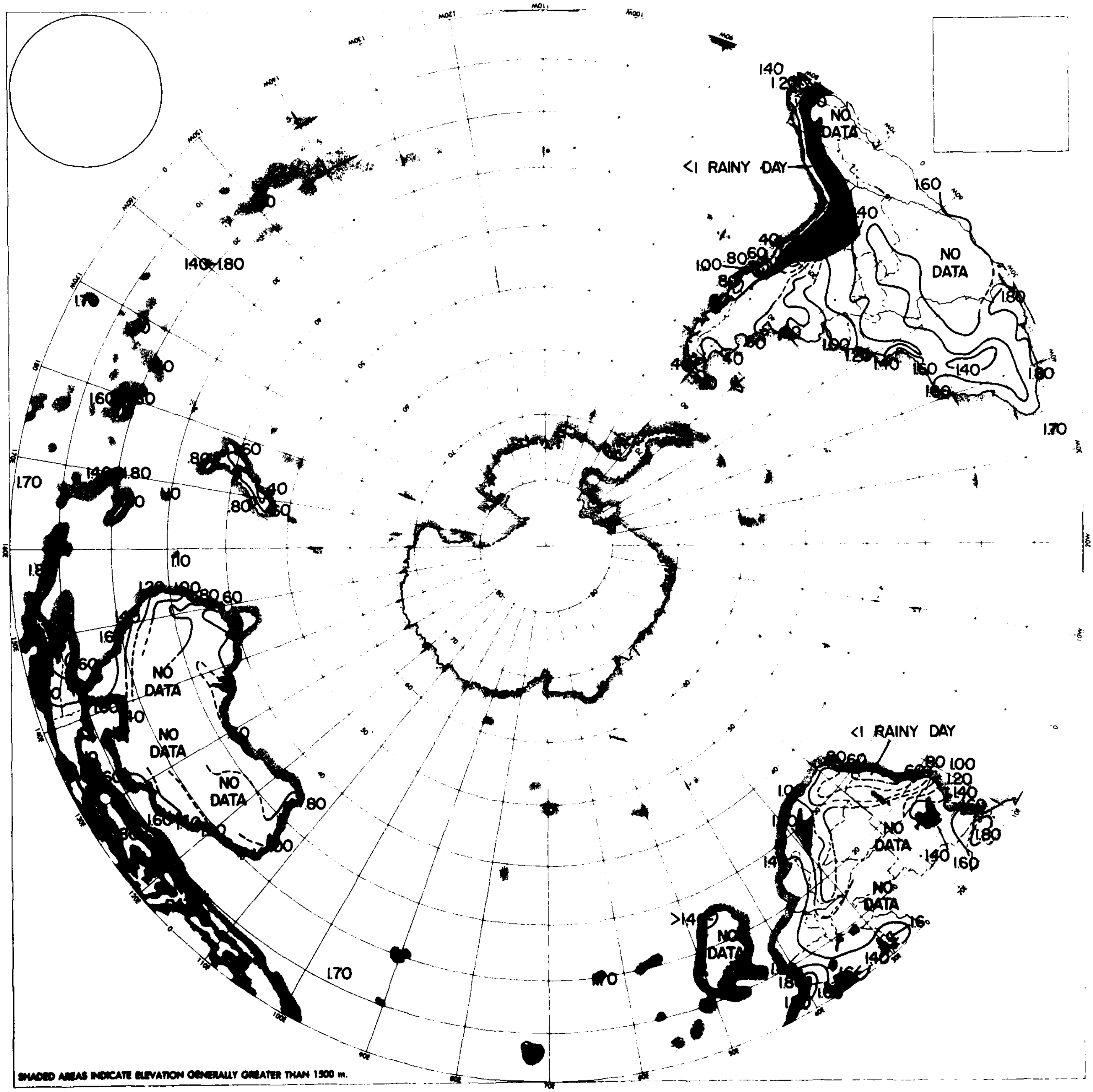

Figure 7. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.01 Percent of the Time in April

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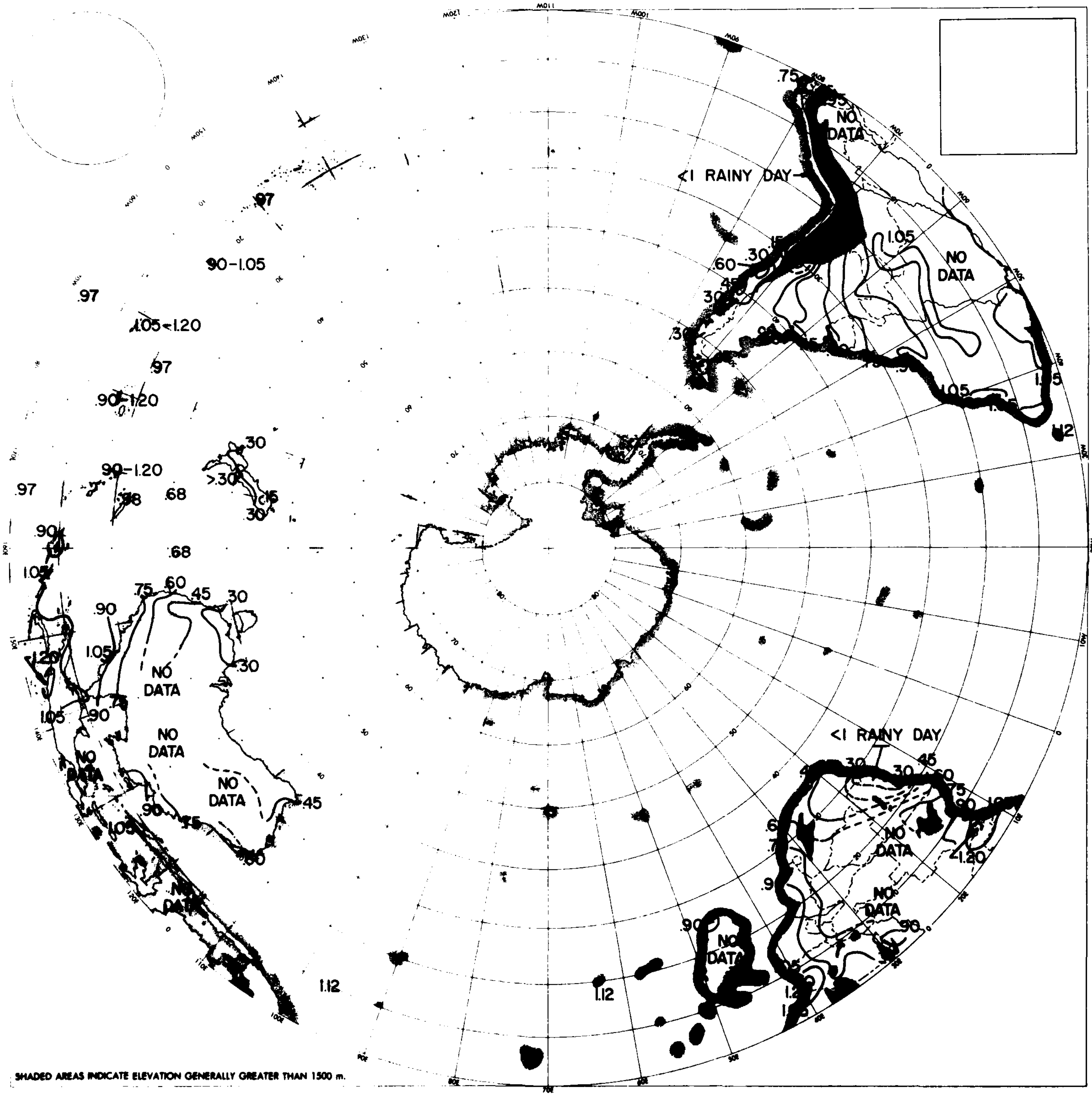

Figure 8. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.05 Percent of the Time in April

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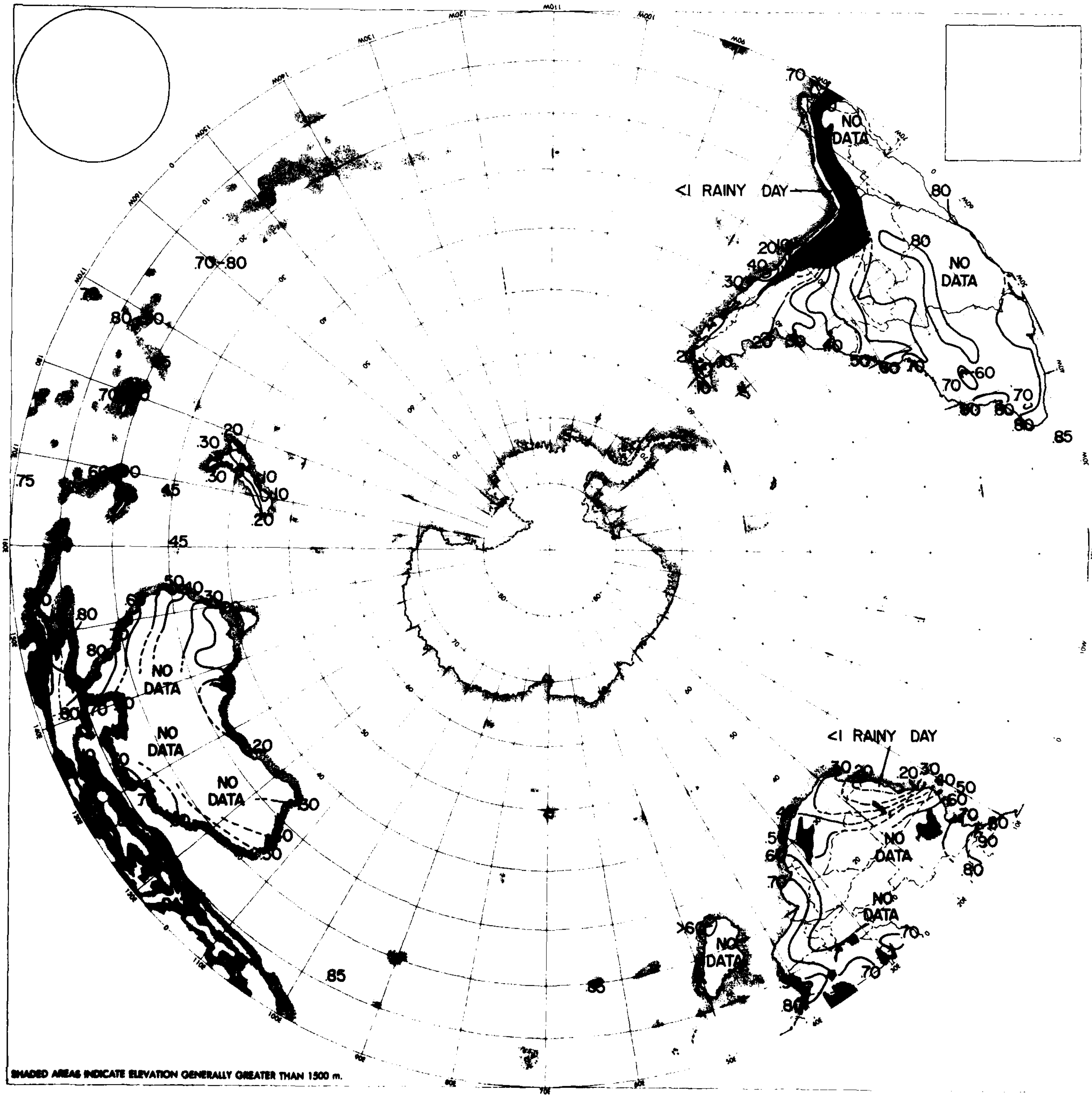

Figure 9. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.10 Percent of the Time in April

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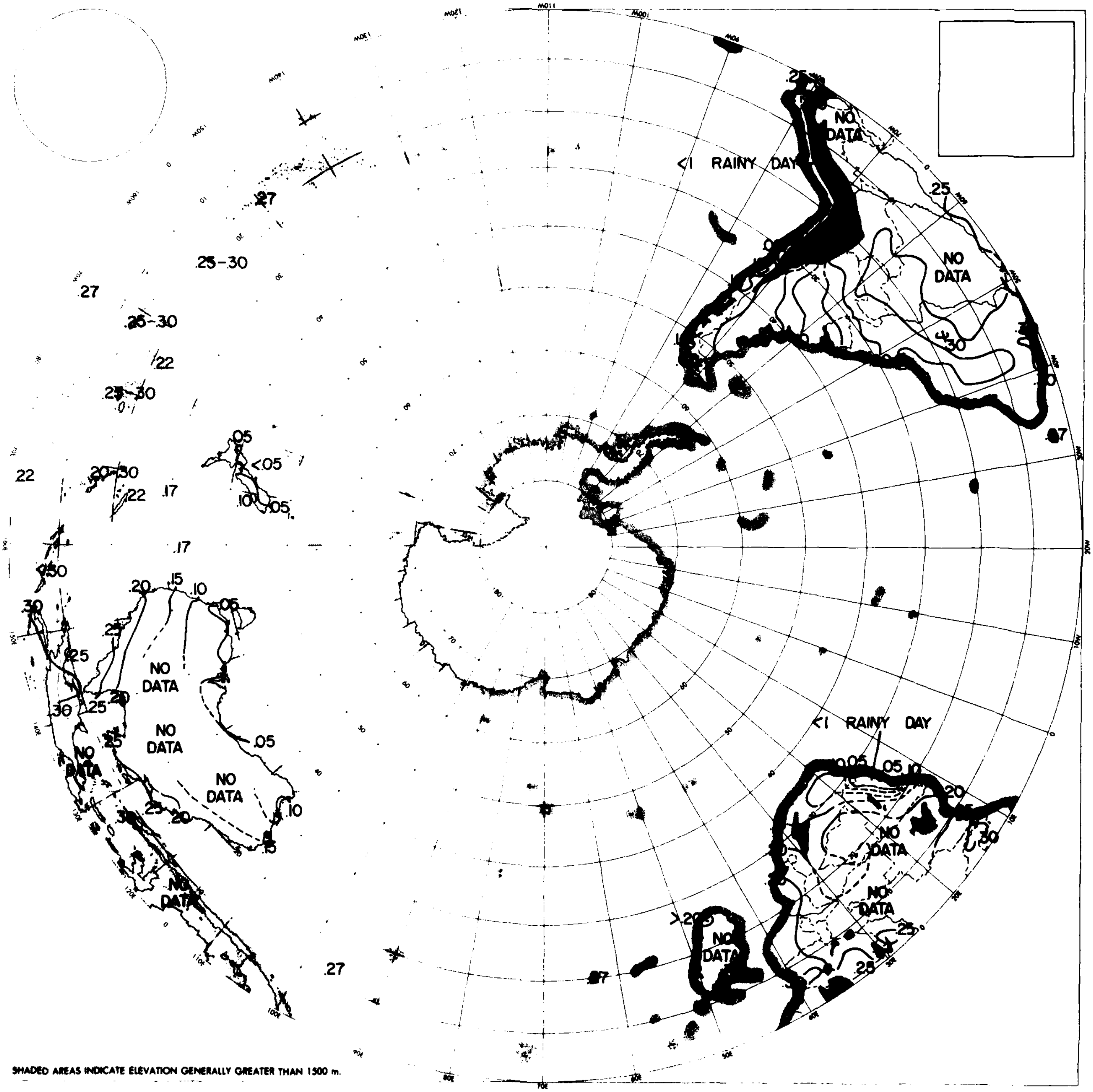

Figure 10. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.50 Percent of the Time in April

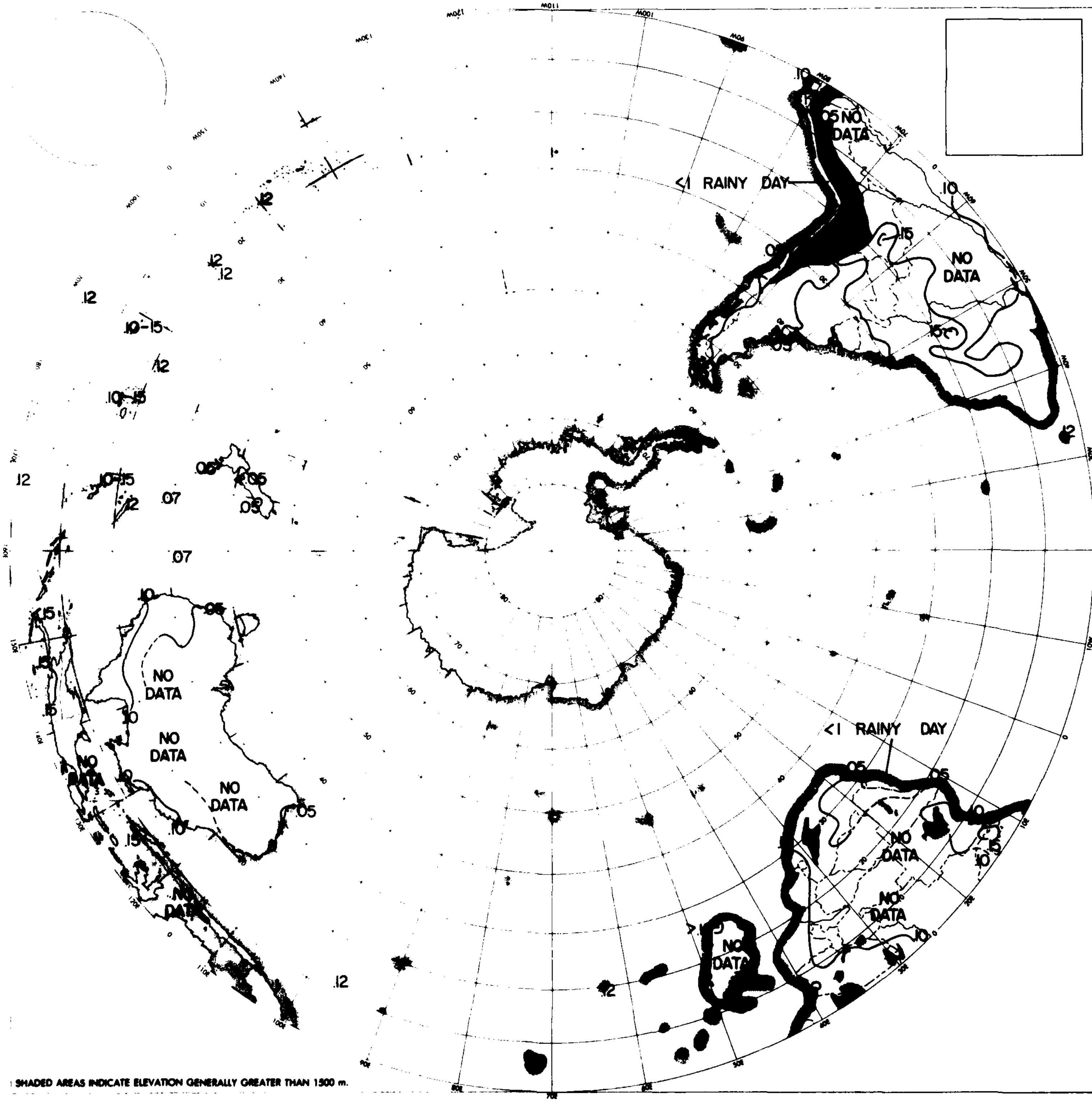

Figure 11. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 1.0 Percent of the Time in April

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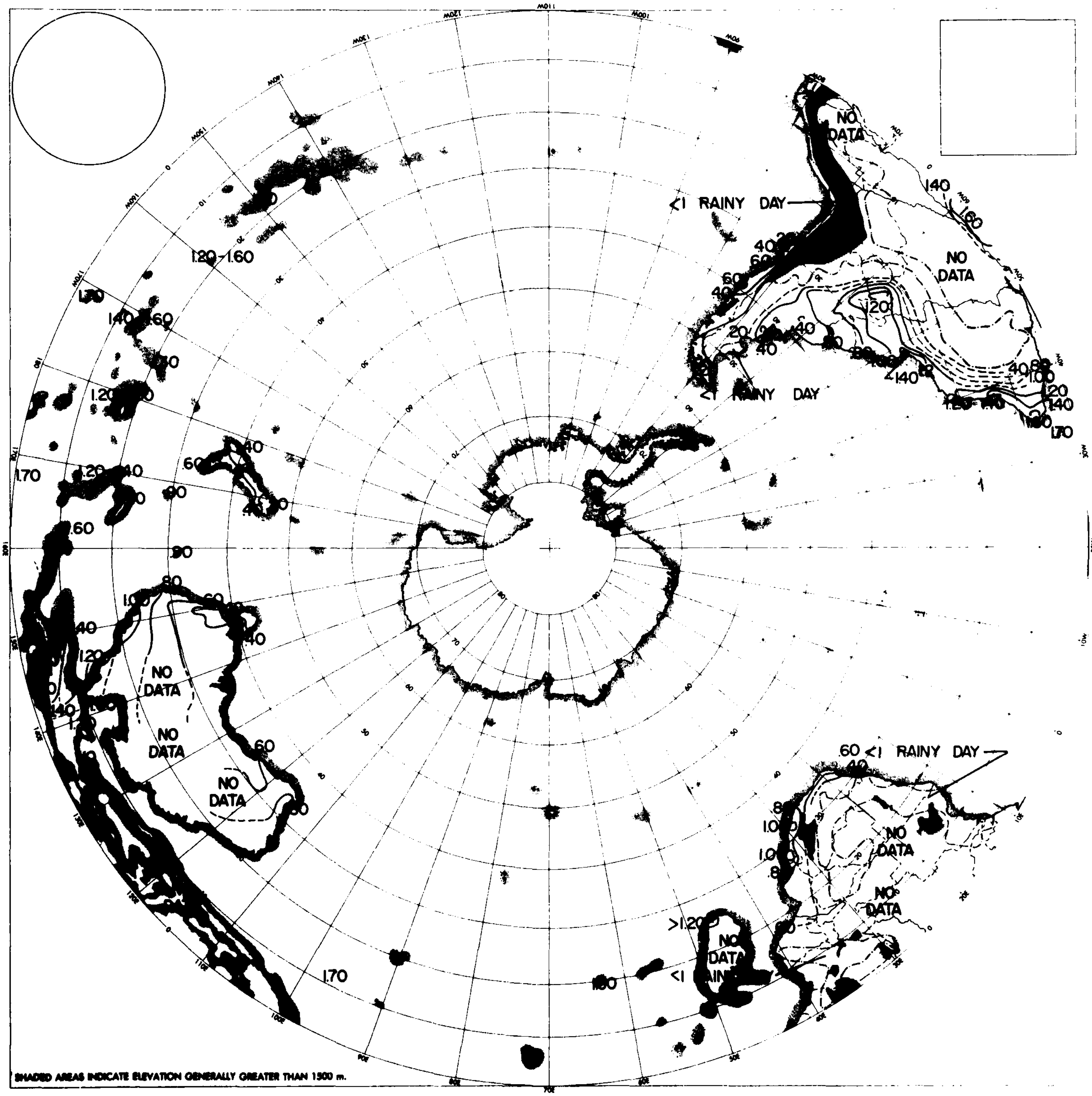

Figure 12. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.01 Percent of the Time in July

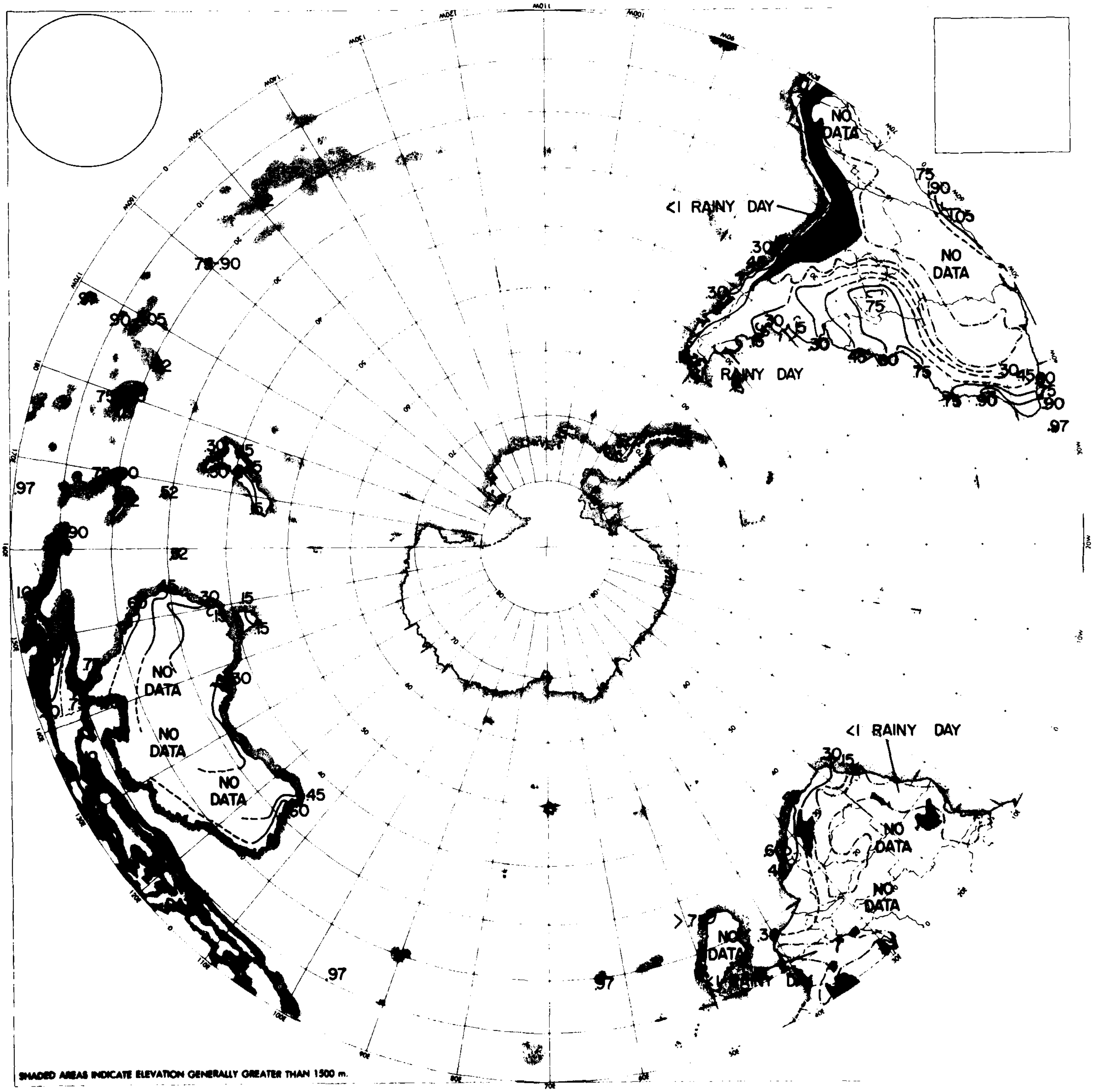

Figure 13. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.05 Percent of the Time in July

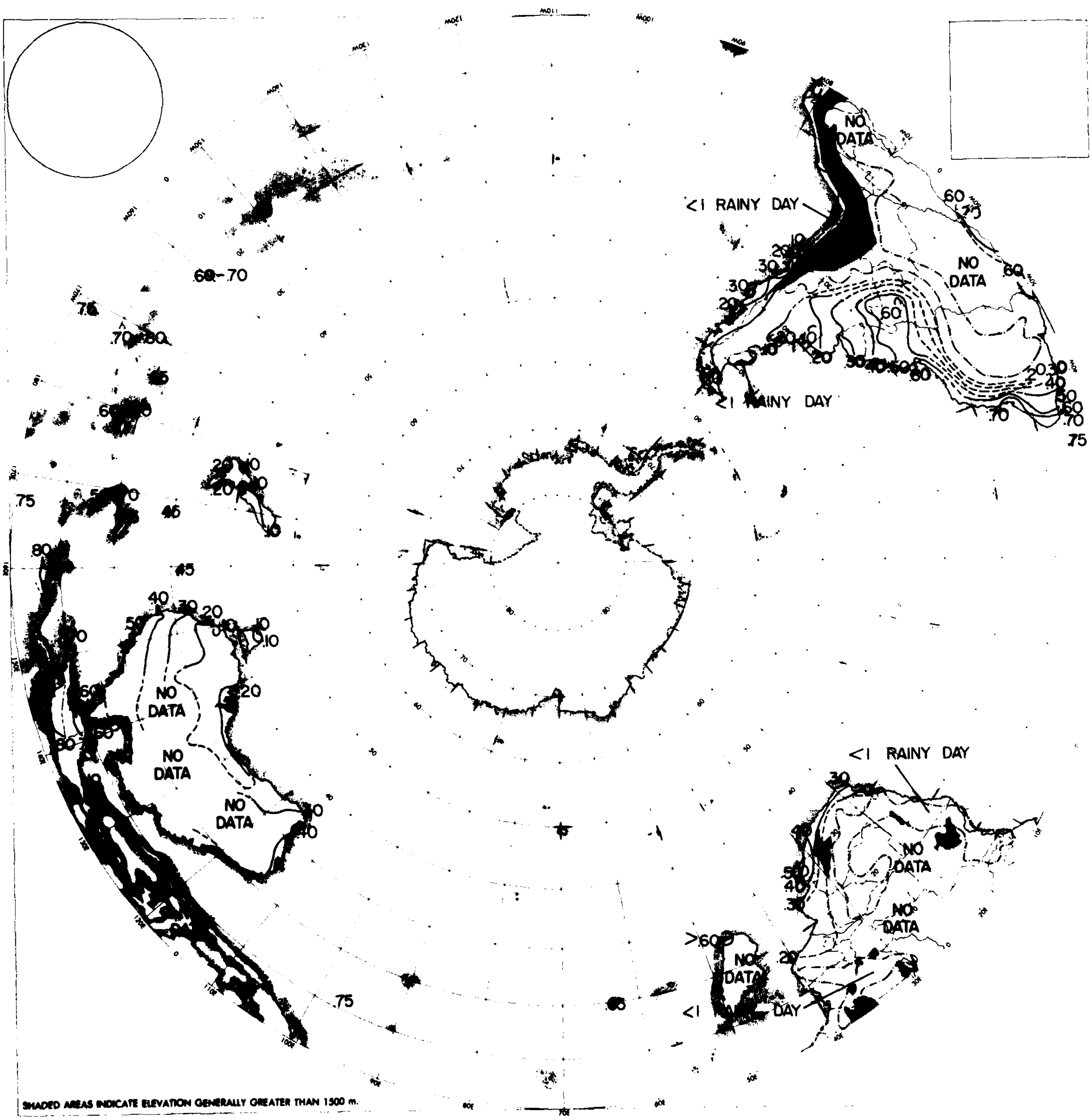

Figure 14. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.10 Percent of the Time in July

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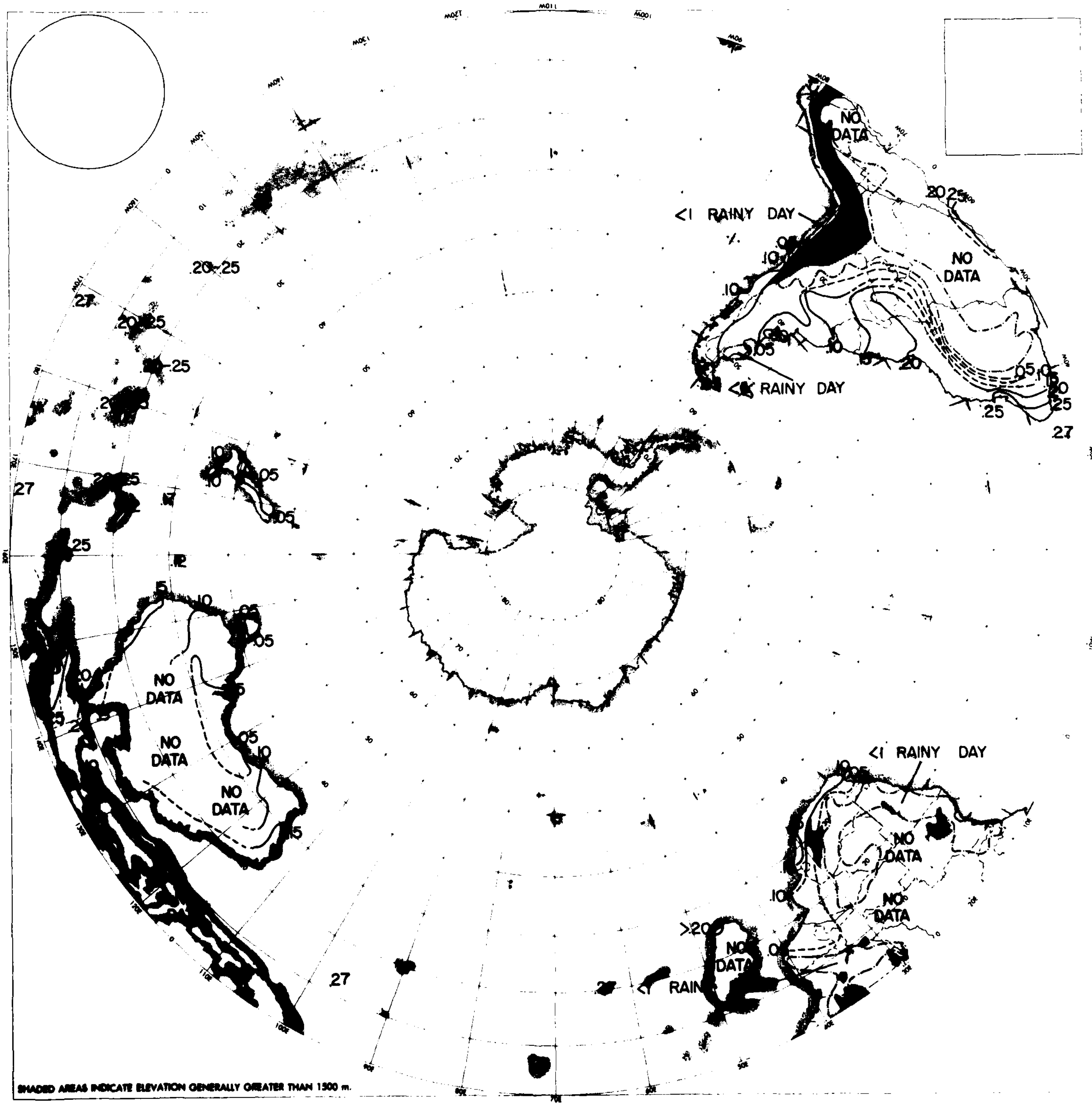

Figure 15. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.50 Percent of the Time in July

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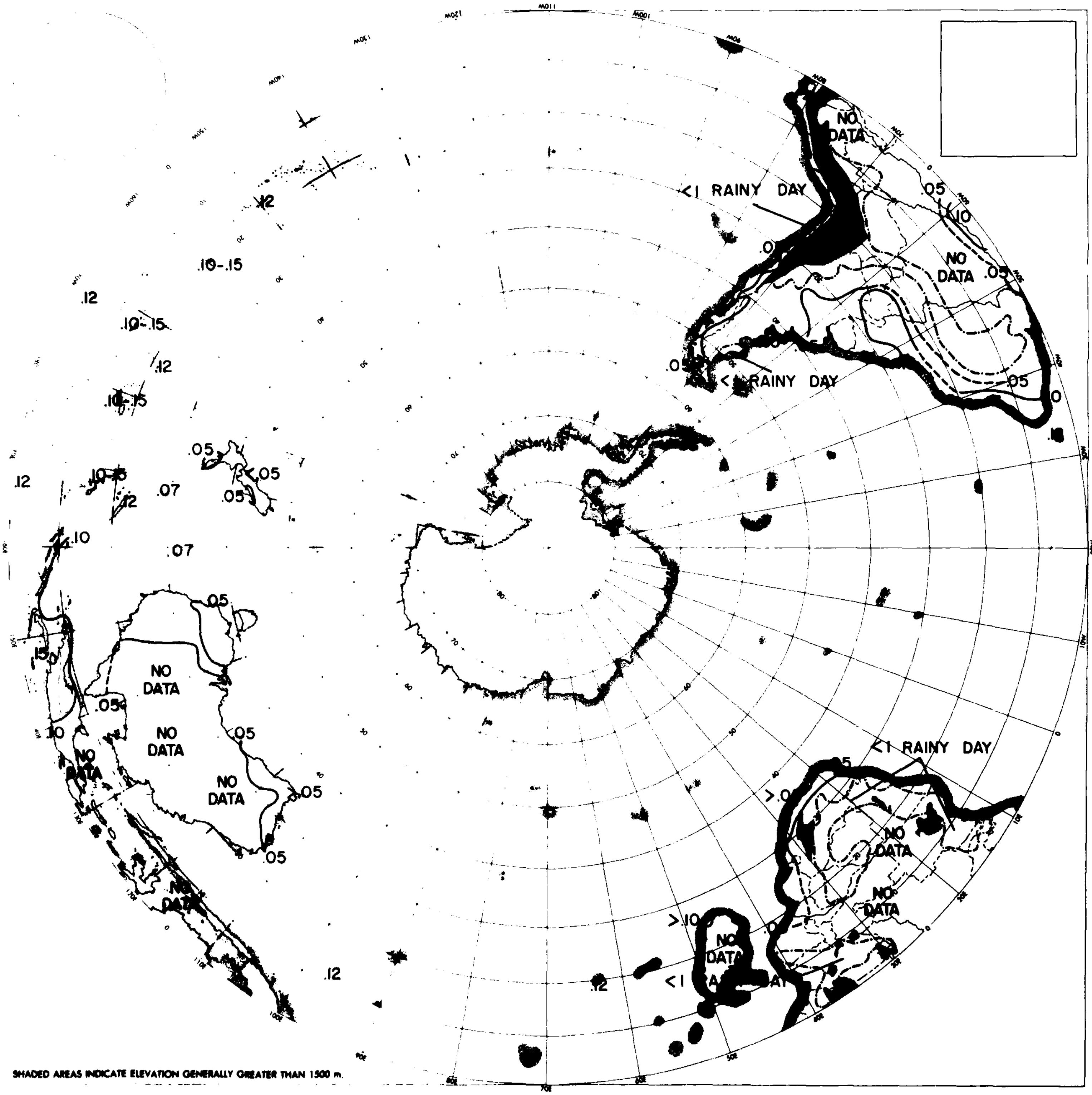

Figure 16. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 1.0 Percent of the Time in July

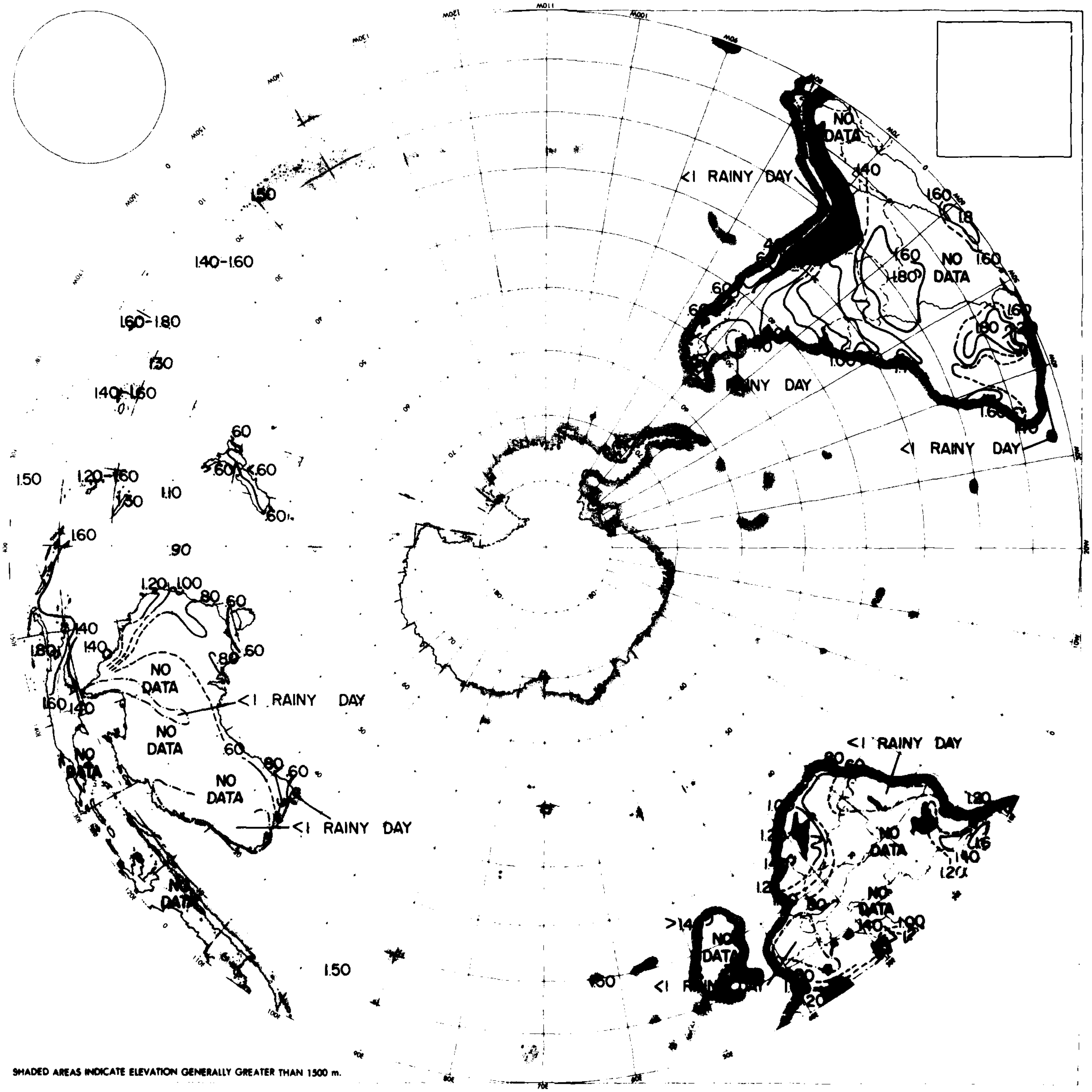

Figure 17. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.01 Percent of the Time in October

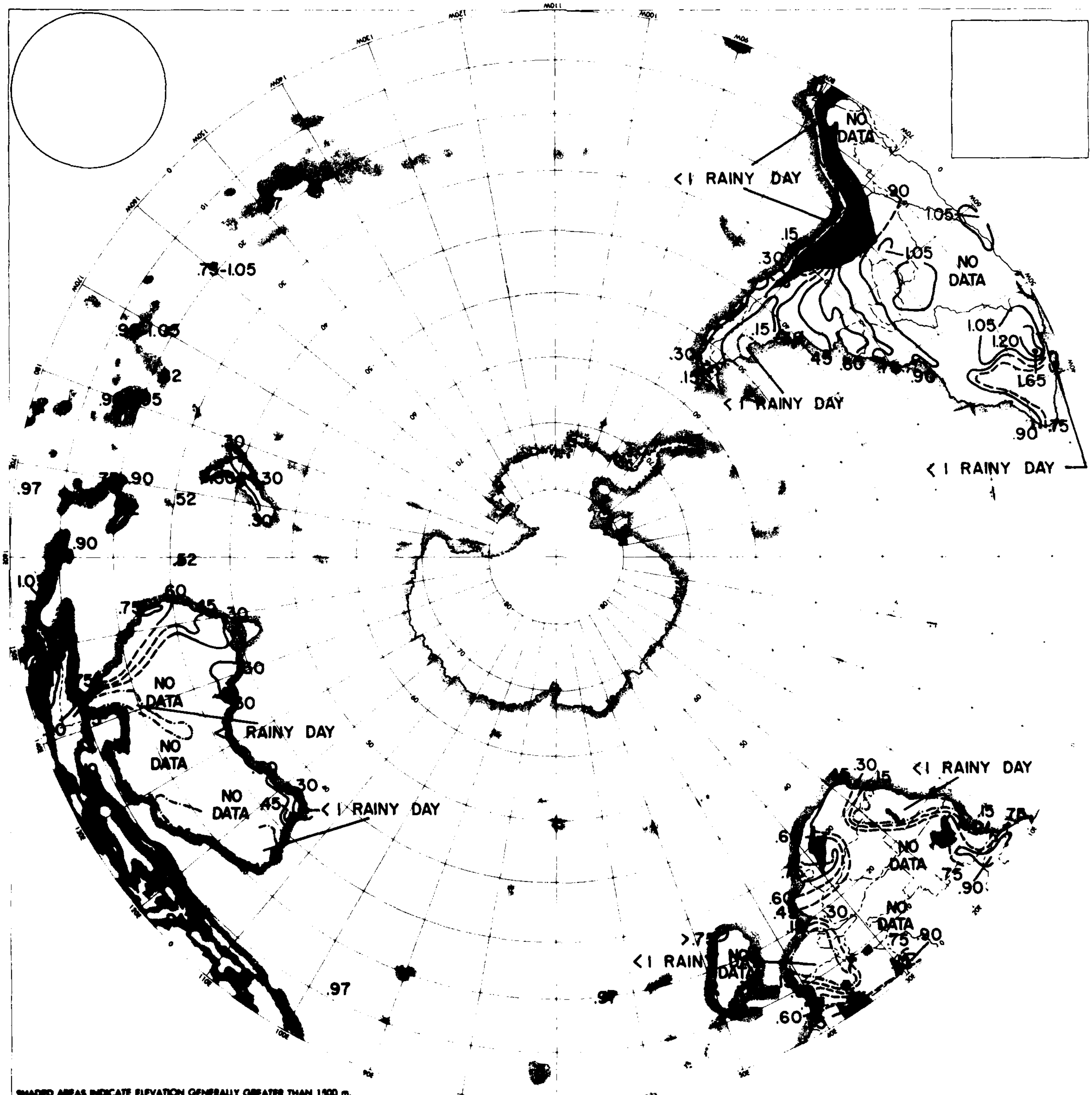

Figure 18. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.05 Percent of the Time in October

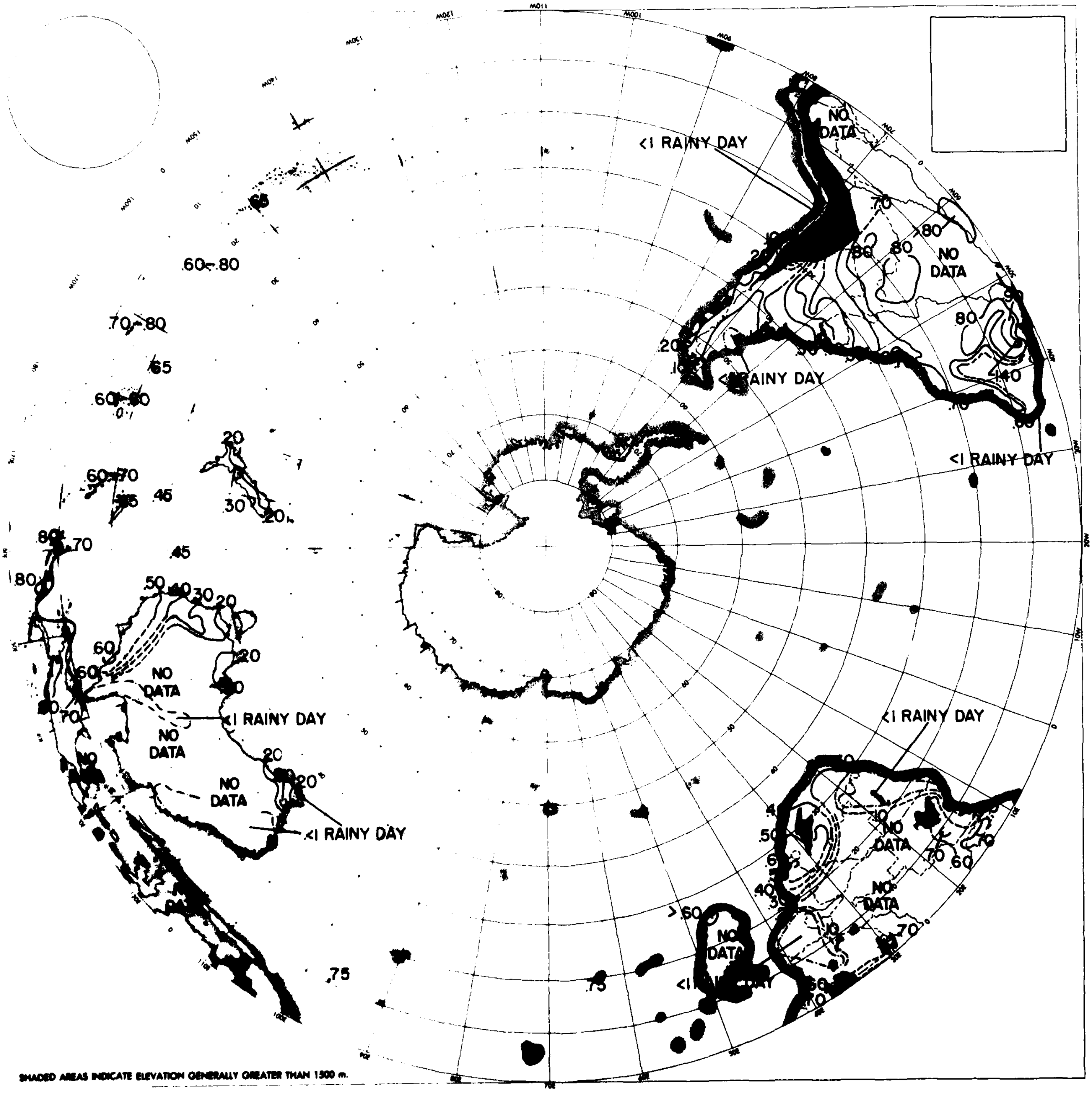

Figure 19. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.10 Percent of the Time in October

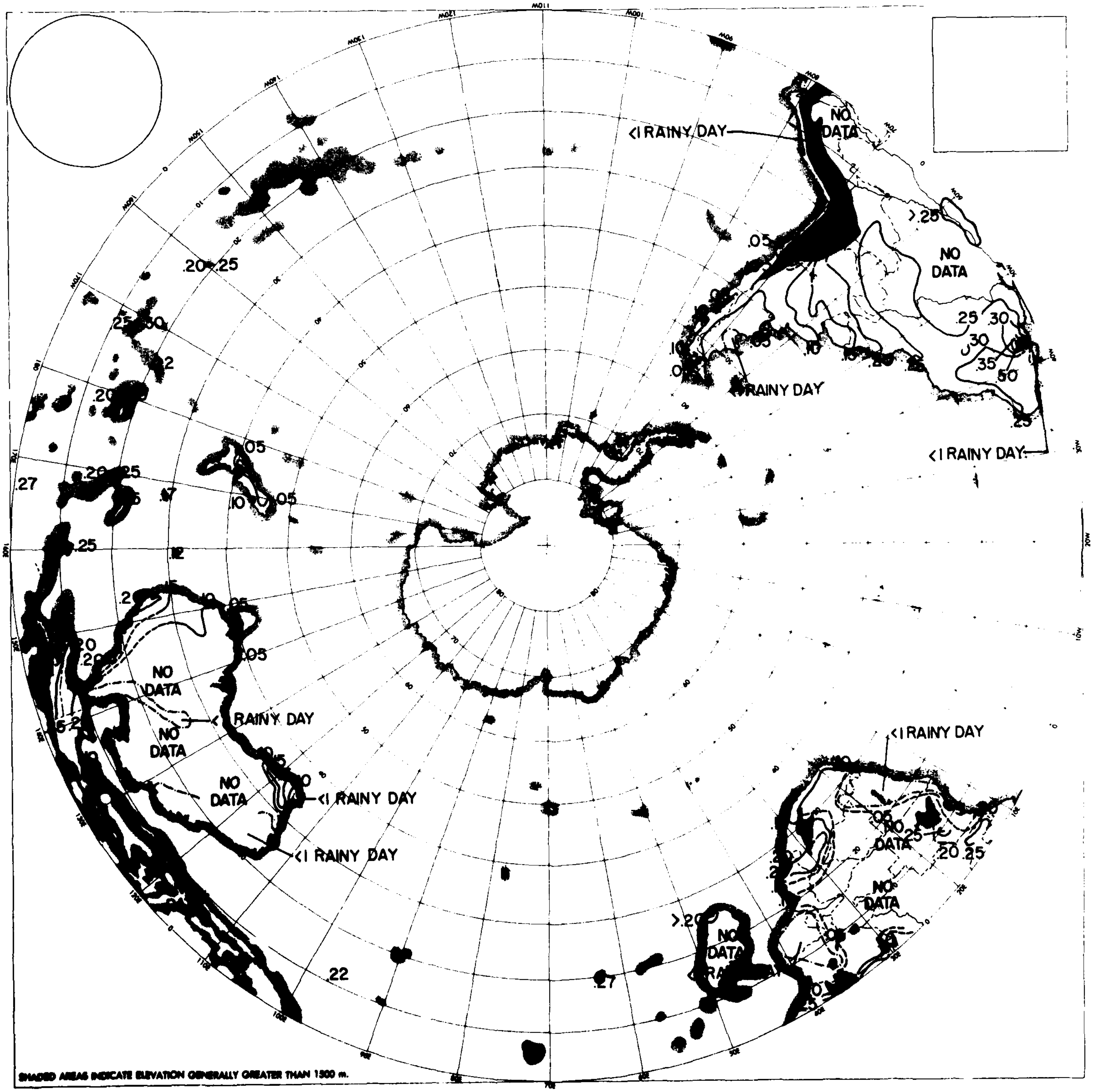

Figure 20. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 0.50 Percent of the Time in October

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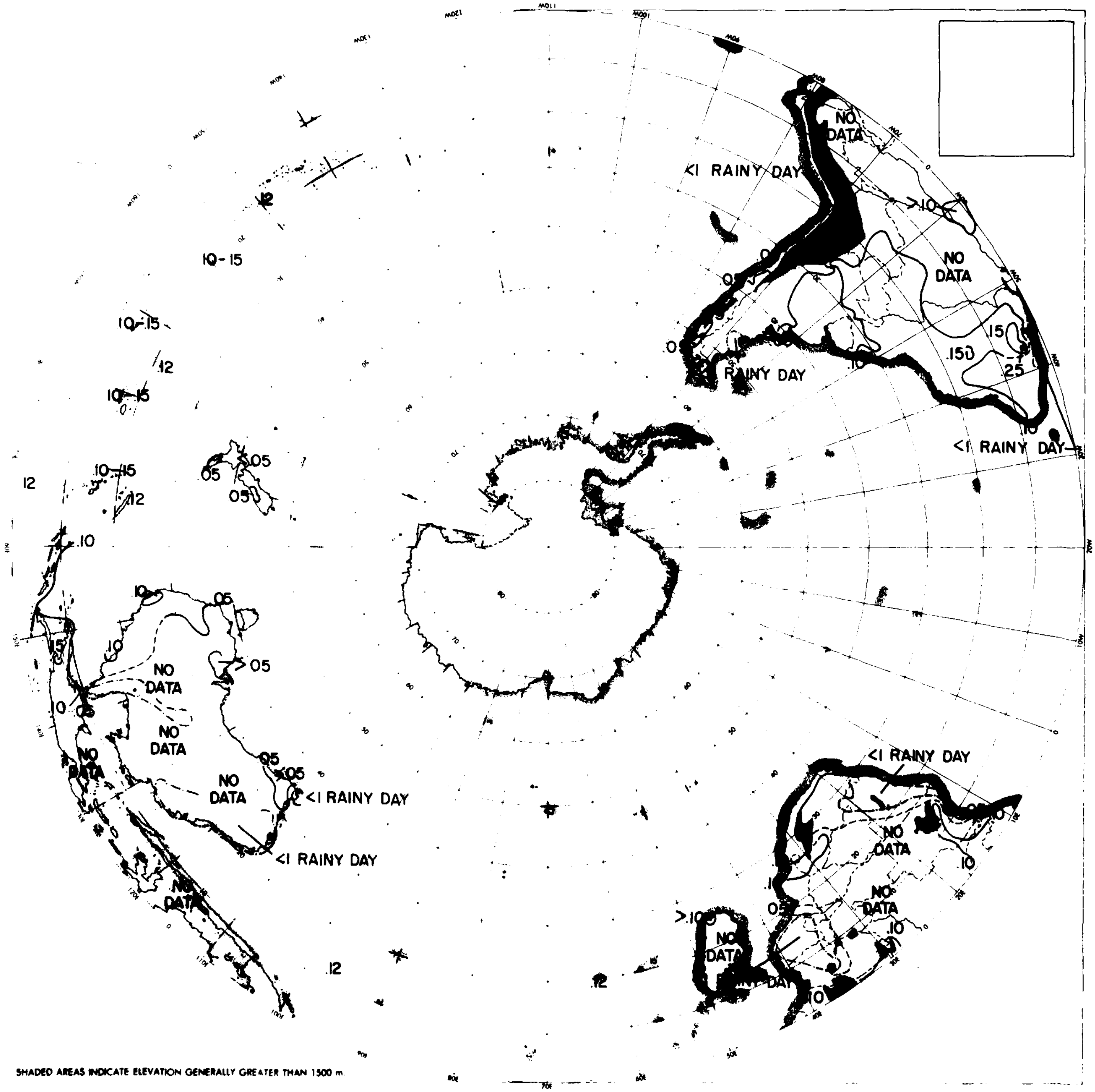

Figure 21. One-Min Rainfall Rate (mm/min) Equalled or Exceeded 1.0 Percent of the Time in October

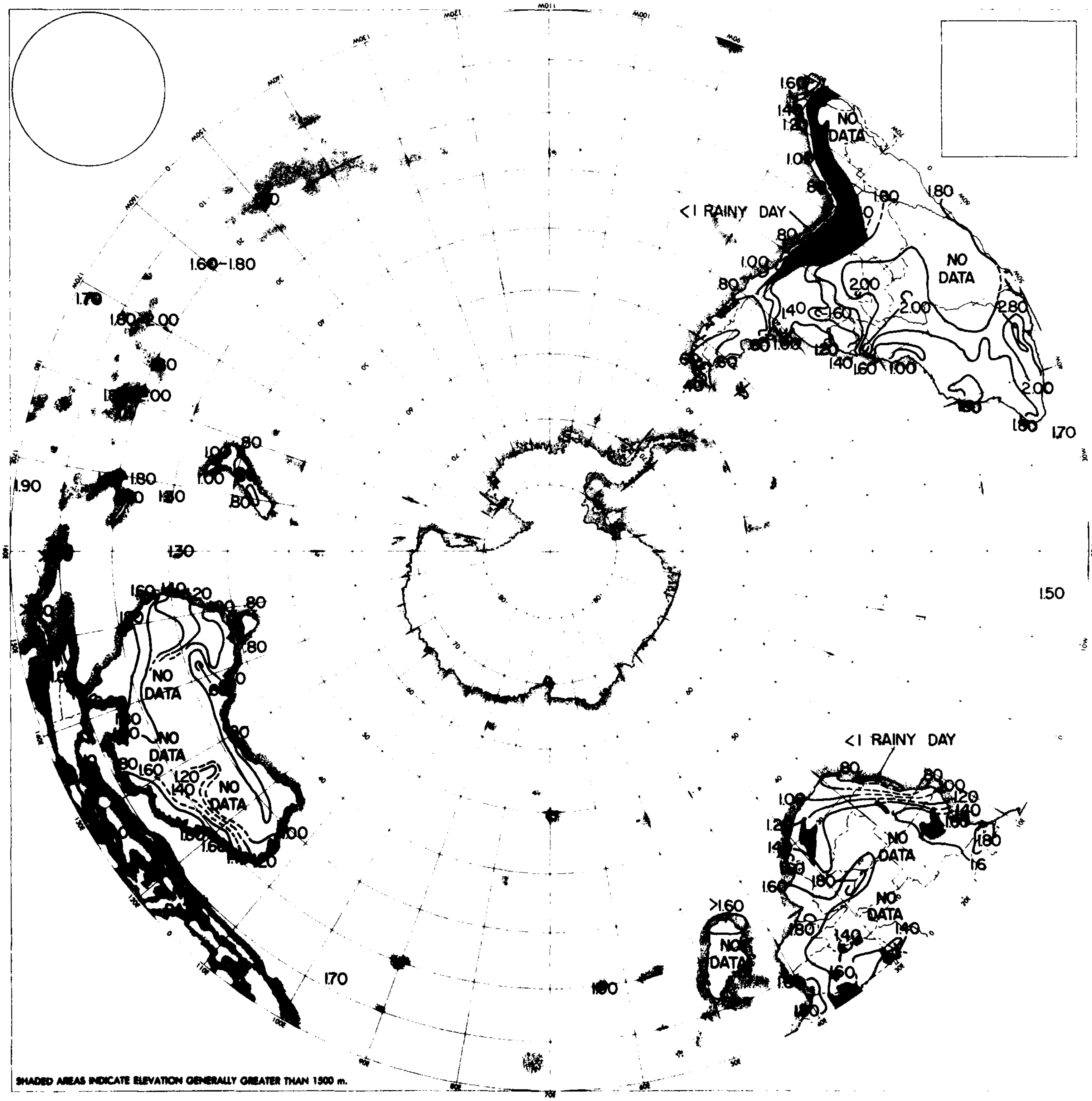

Figure 22. Highest 1-Min Rainfall Rates (mm/min) Equalled or Exceeded 0.01 Percent of the Time in Any Month

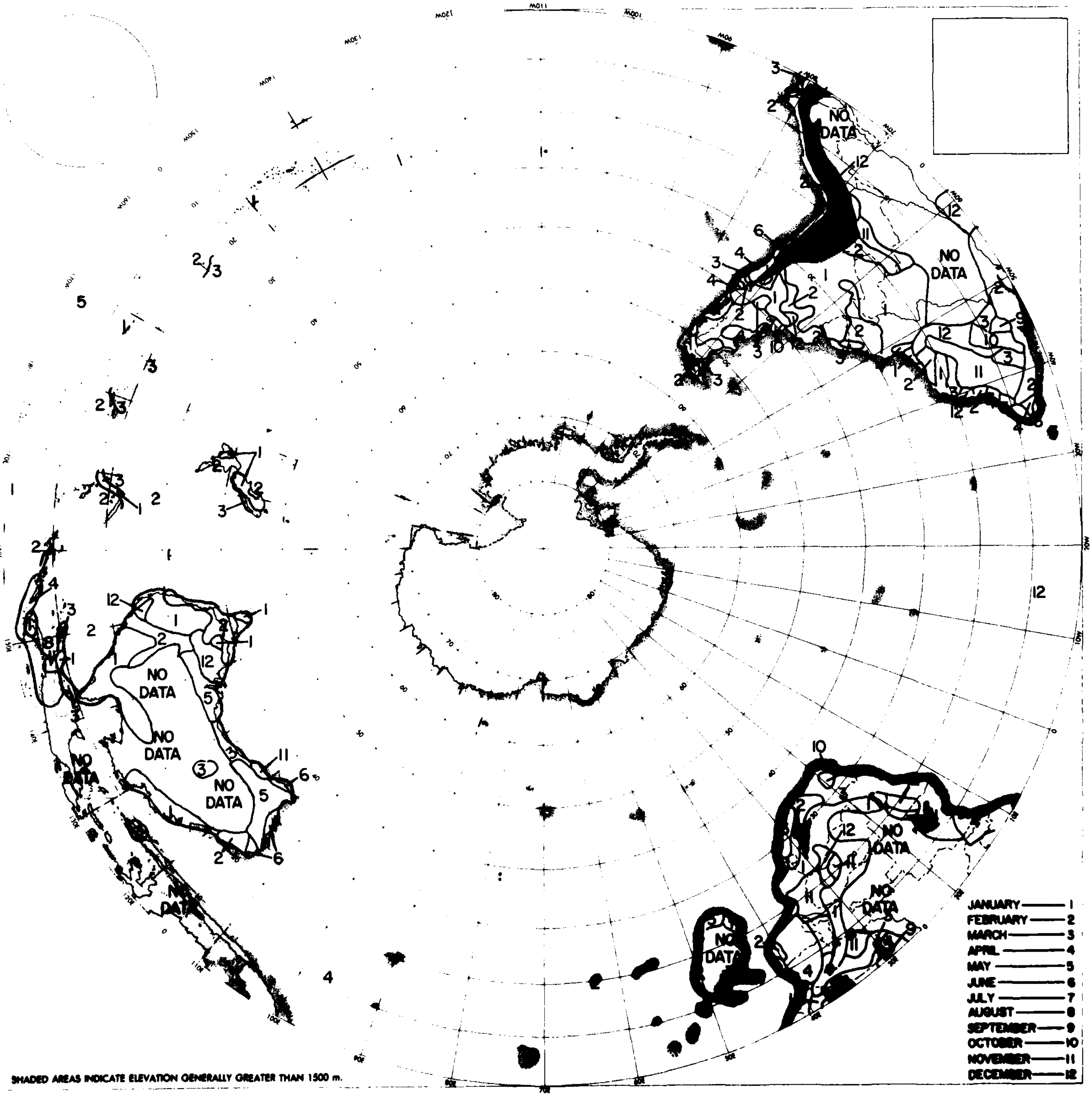

Figure 23. Month With the Highest 1-Min Rainfall Rates Equalled or Exceeded 0.01 Percent of the Time

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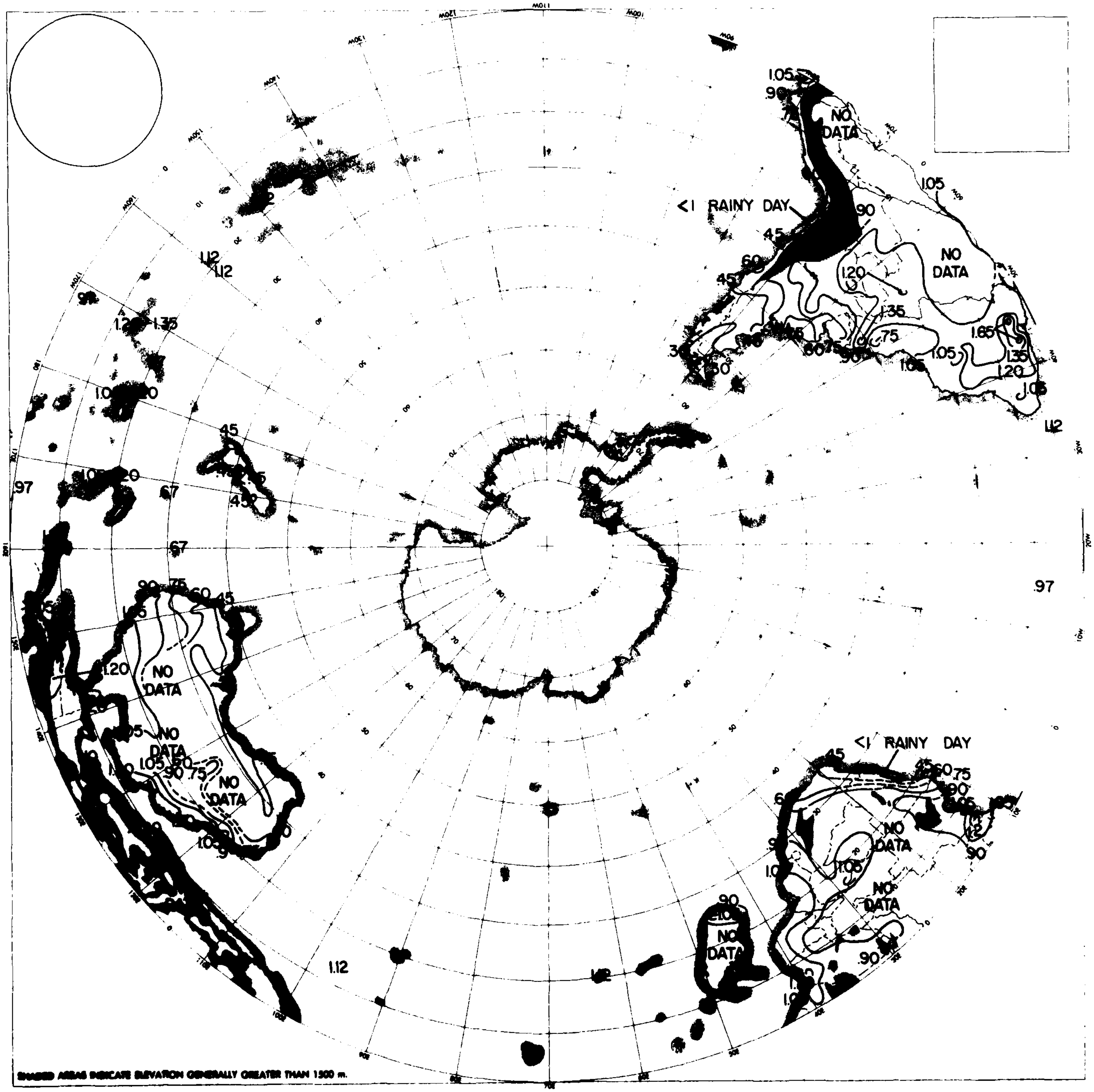

Figure 24. Highest 1-Min Rainfall Rates (mm/min) Equalled or Exceeded 0.05 Percent of the Time in Any Month

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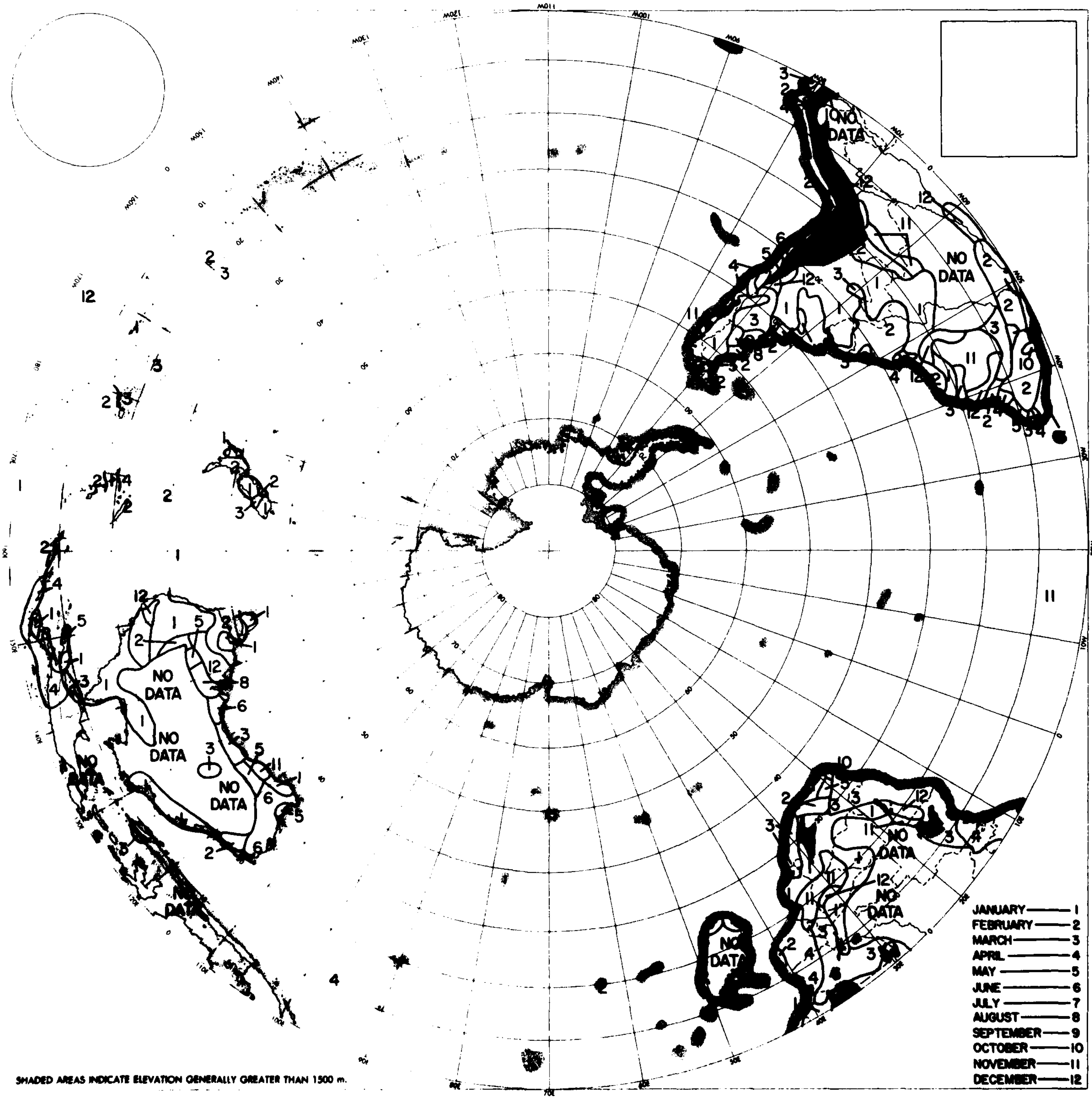

Figure 25. Month With the Highest 1-Min Rainfall Rates Equalled or Exceeded 0.05 Percent of the Time

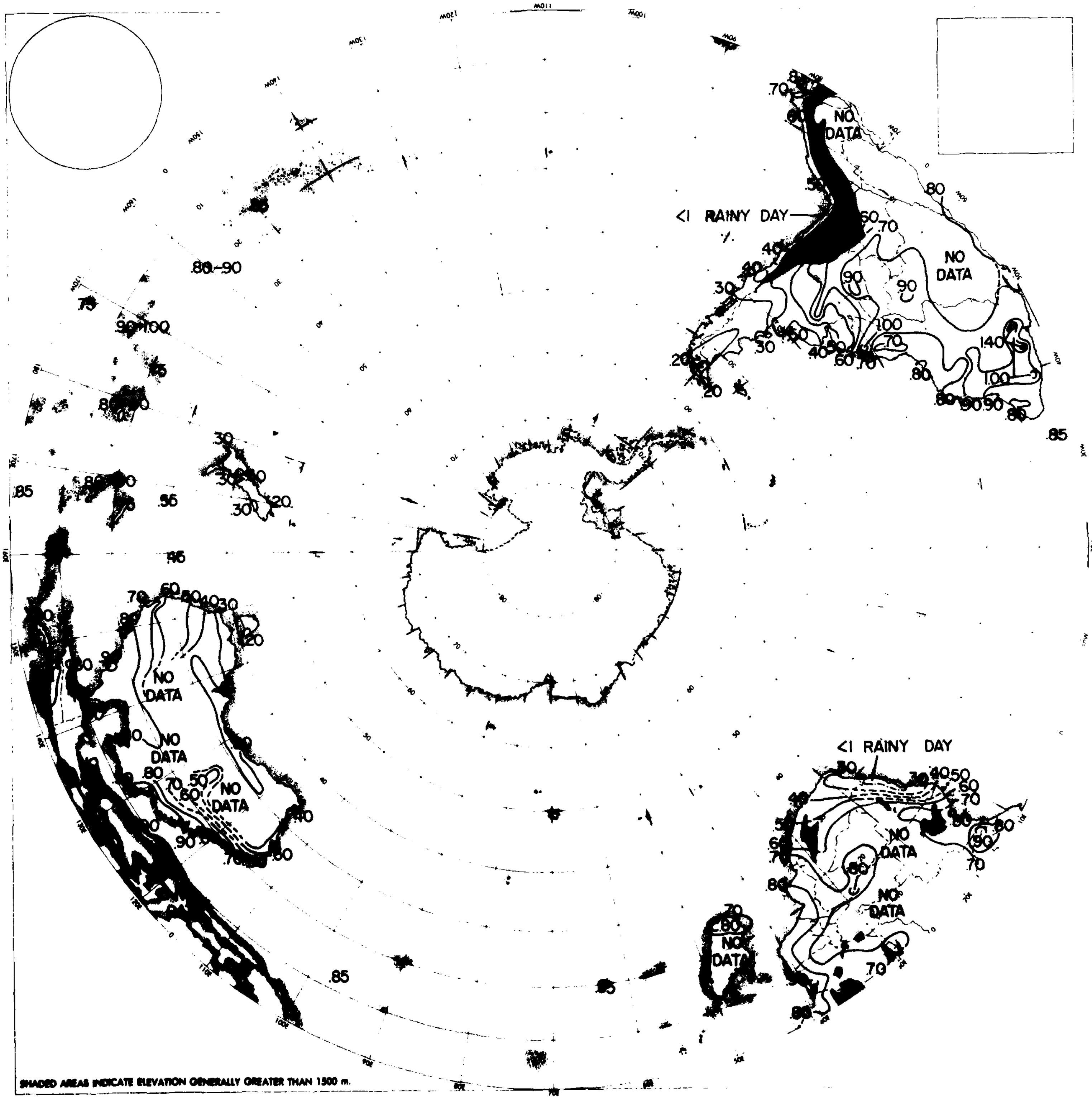

Figure 26. Highest 1-Min Rainfall Rates (mm/min) Equalled or Exceeded 0.10 Percent of the Time in Any Month

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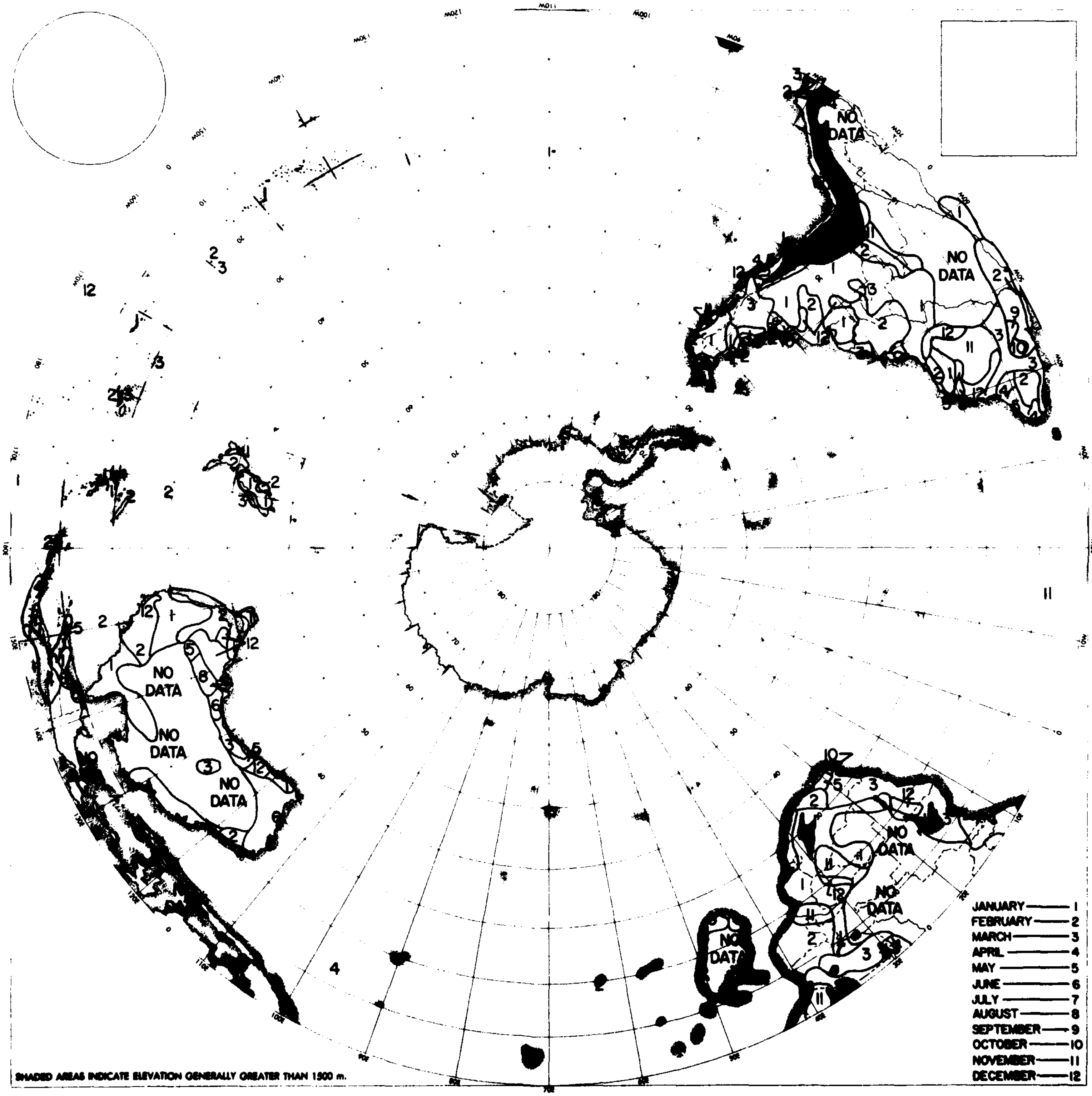

Figure 27. Month With the Highest 1-Min Rainfall Rates Equalled or Exceeded 0.10 Percent of the Time

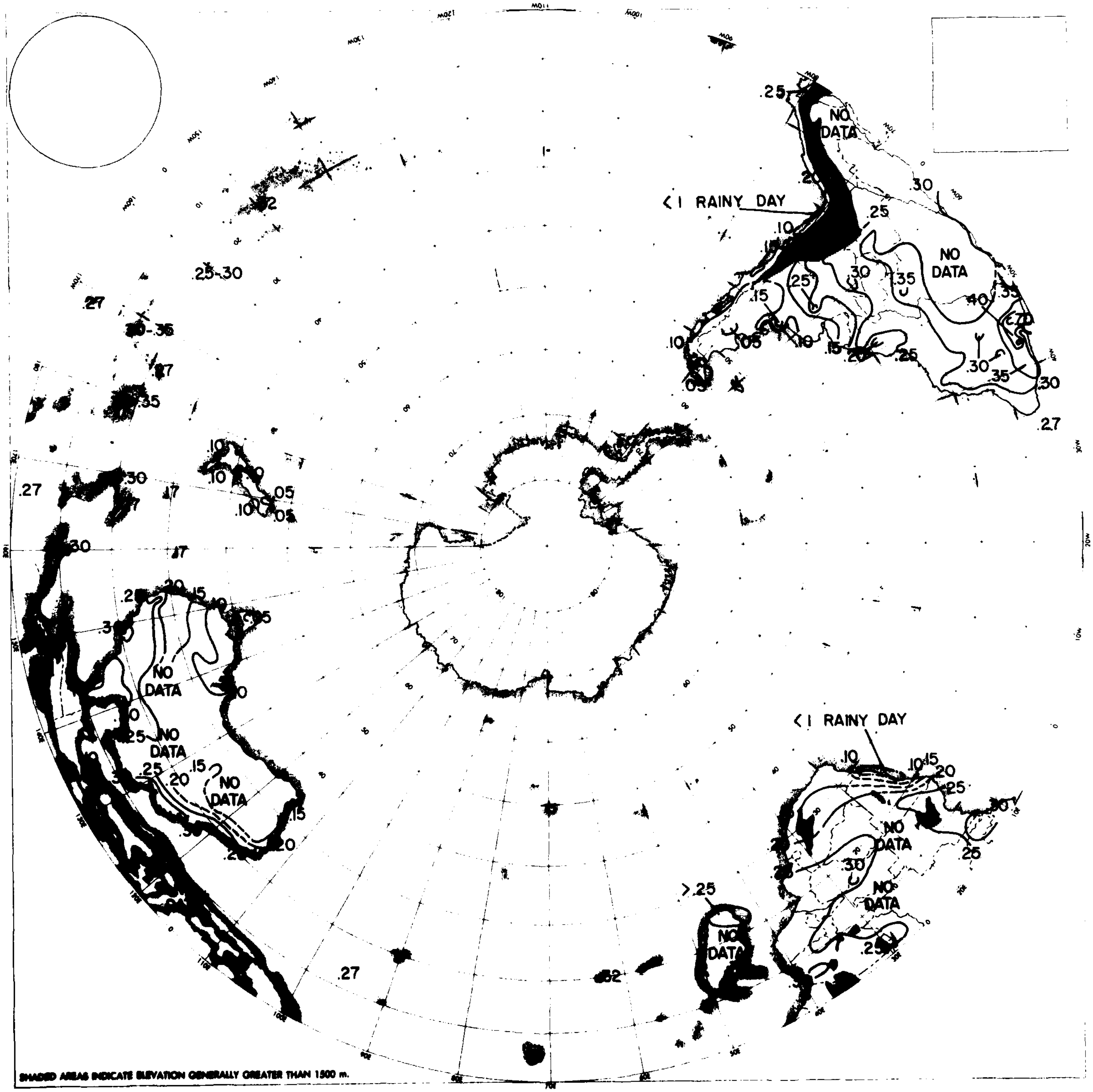

Figure 28. Highest 1-Min Rainfall Rates (mm/min) Equalled or Exceeded 0.50 Percent of the Time in Any Month

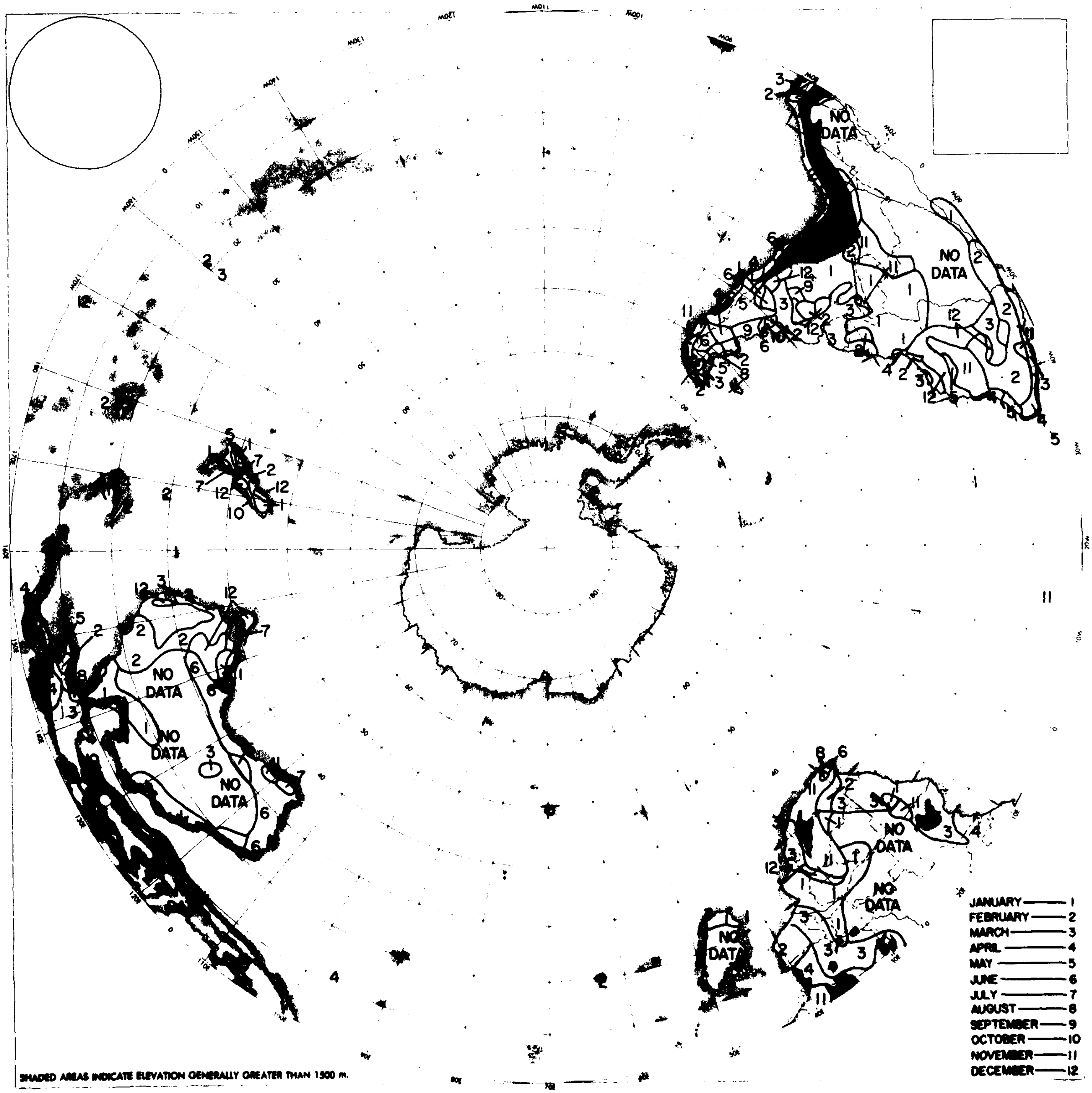

Figure 29. Month With the Highest 1-Min Rainfall Rates Equalled or Exceeded 0.50 Percent of the Time

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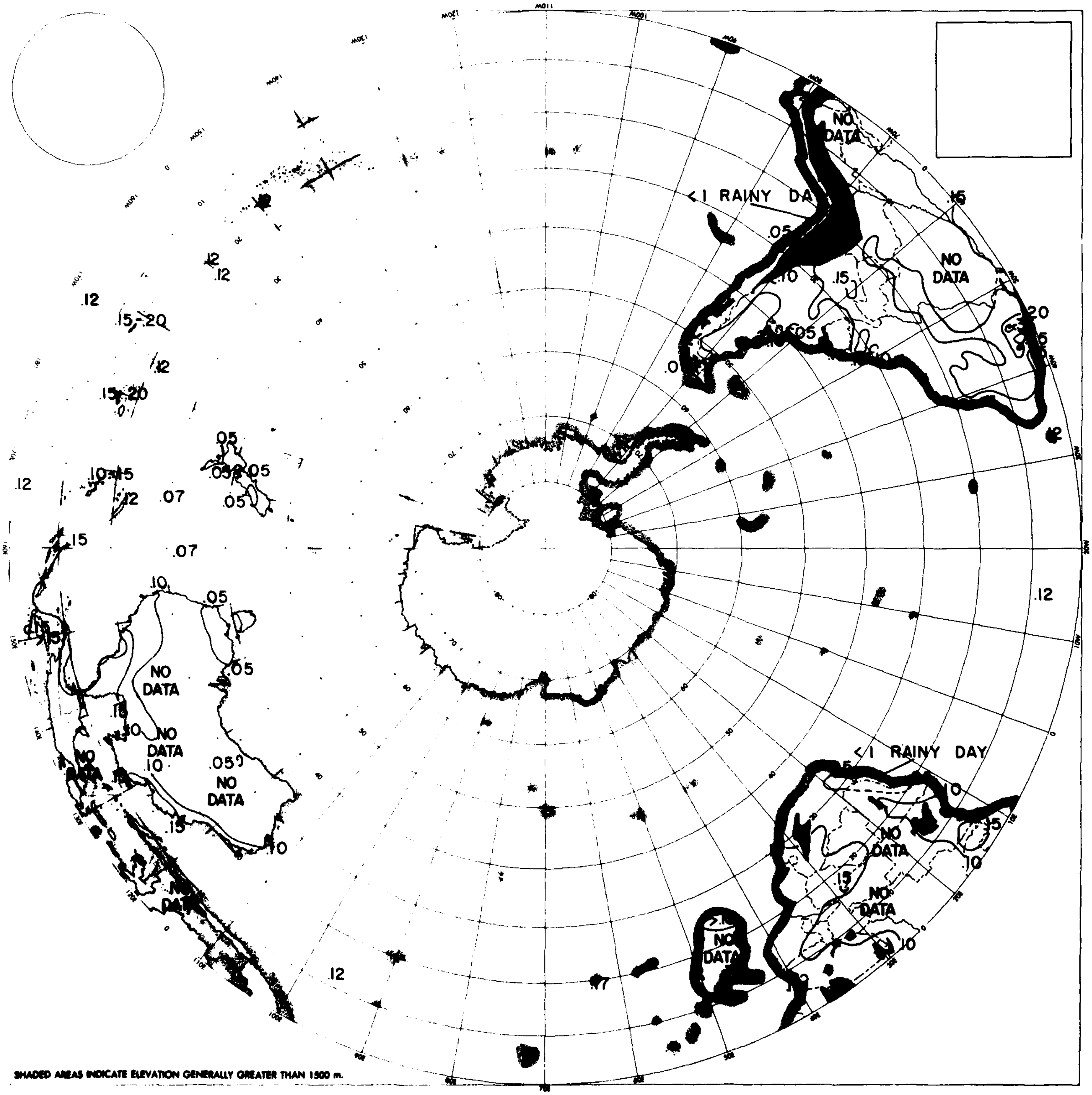

Figure 30. Highest 1-Min Rainfall Rates (mm/min) Equalled or Exceeded 1.0 Percent of the Time in Any Month

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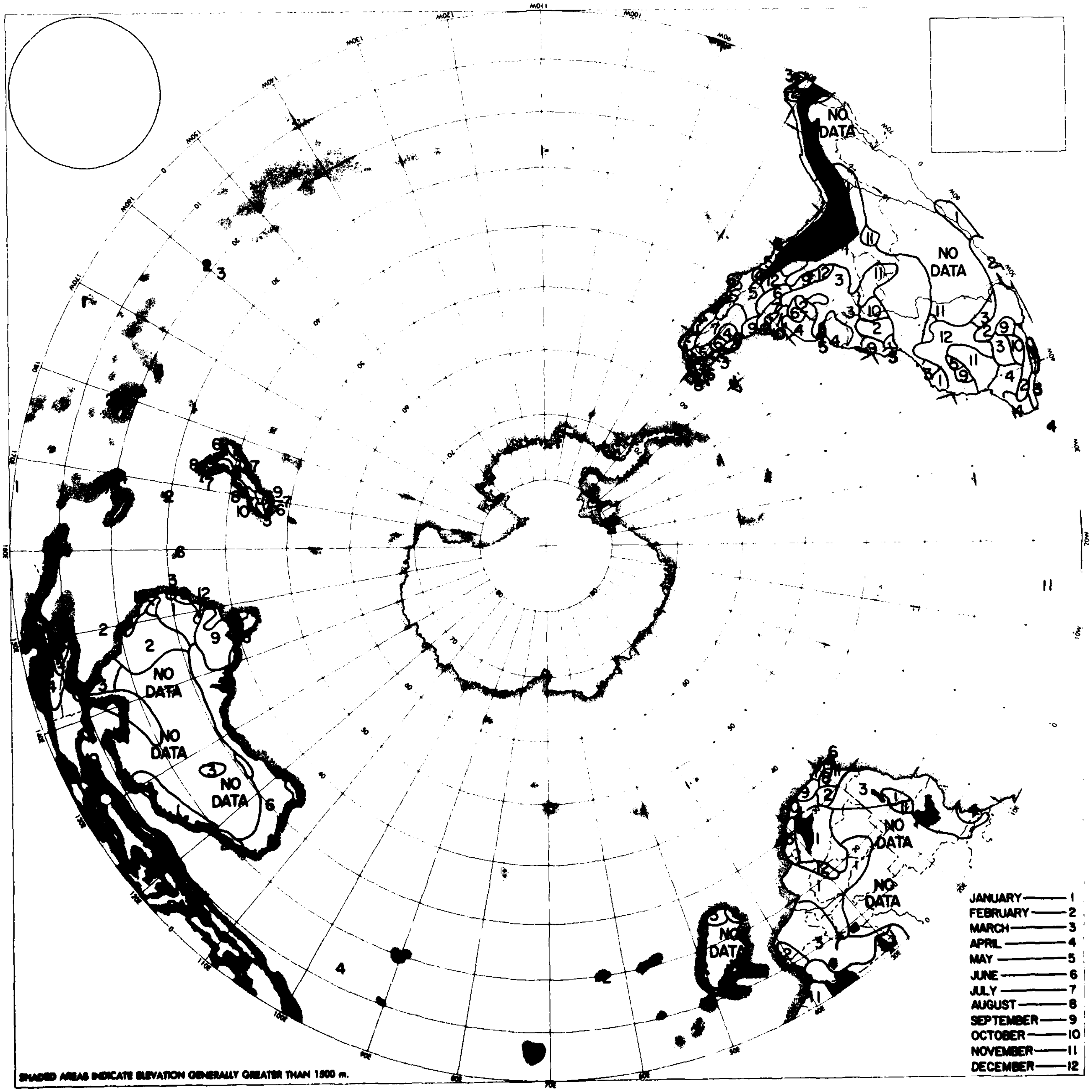

Figure 31. Month of the Year With the Highest 1-Min Rainfall Rates Equalled or Exceeded 1.0 Percent of the Time

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